ADVANCED LESSONS IN HUMAN PHYSIOLOGY & HYGIENE ...

WINFRED EUGENE BALDWIN

Advanced Lessons in Human Physiology & Hygiene ...

Winfred Eugene Baldwin

THE PRACTICAL SERIES OF SCHOOL PHYSIOLOGIES

ADVANCED LESSONS

IN

HUMAN PHYSIOLOGY

AND HYGIENE

FOR GRAMMAR, UNGRADED, AND HIGH SCHOOLS

BY

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VERY FULLY ILLUSTRATED

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PREFACE.

This book claims recognition on account of the distinctively practical character of its lessons. Although much attention is devoted to anatomy and physiology, it is only because a clear understanding of these subjects is indispensable to a correct knowledge of hygiene. No person can have an intelligent comprehension of the laws of health unless he is familiar with the structure of the human body and the functions of its several parts. In this volume those physiological facts which are most necessary to be known are told in language easily understood and with all desirable fullness. The aim has been to present the various subjects in their logical order, each chapter, as in a continued story, leading up to and suggesting the chapter which follows. Pupils are encouraged to form conclusions of their own. The practical questions which frequently occur are so framed as to elicit original thought. The review questions are intended not so much to test the memory as to draw forth opinions and suggest practical applications of the truths learned. Many other deviations from the usual style and manner of books on this subject will be noticed. Part First, including about three fourths of the work, is devoted to a study of the body and the functions and preservation of its parts—thus presenting anatomy, physiology, and hygiene in their inseparable relations. Part Second is devoted entirely to hygienic subjects—food, drink, clothing,

exercise, habits of life, cleanliness, ventilation, extraneous influences upon health, and the means of restoring lost vigor and of combating disease. Special attention is given to the nature and effects of alcohol and other narcotics, thus meeting the requirements, in this respect, of the laws relating to such study. The demand for school instruction regarding the prevention of contagious diseases is met in a carefully prepared chapter on that subject. Other chapters on first aid to the injured and on the proper care of the sick, giving concise directions easily comprehended by everybody, add still further to the practical value of the work. Throughout the volume the author has endeavored to avoid technicalities and to present every statement in such a way that the youngest pupil may readily comprehend its meaning. The audience which he has had in mind is not one of medical students, but is composed of young people in grammar, ungraded, and high schools, who study these subjects in order to acquire intelligent ideas regarding the preservation of their own health, the development of their strength, and the general betterment of their lives.

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PART I.

THE HUMAN BODY, ITS STRUCTURE AND FUNCTIONS.

ANATOMY, PHYSIOLOGY, AND HYGIENE.

HUMAN PHYSIOLOGY AND HYGIENE.

I.—MAN'S PLACE IN NATURE.

1. **Man** is a creature of so complex a nature that to know him, he must be studied in various aspects and from many different points of view. This fact has given rise to several sciences, each of which has man as its subject. Psychology, viewing him as a *rational being*, has for its object the investigation of the principles which underlie and control the operations of his mind. Ethics, regarding him in his relations to his fellow men, is concerned with the examination and discussion of the duties which he owes to himself and others as an intelligent *moral agent*. Theology, although seeking primarily to learn all that may be known about God, nevertheless includes a comprehensive study of man as a *spiritual being* having certain well-defined relations and obligations to his Creator. Anatomy and Physiology, recognizing only his corporeal existence, and therefore viewing him simply in his character as an *animal* of the highest order, have for their object the study of his body, its appearance, its structure, and the functions of its various organs and parts.

These four branches of knowledge treat of man in

his fourfold nature; that is, as the possessor of reason, of a moral sense, of a spiritual nature, and of a material body. In the studies in which we are about to engage we shall consider him only as regards the last of these endowments.

From *Anatomy* we shall learn the most general and important facts concerning the structure of the human body, and the composition, shape, and appearance of its various parts.

From *Physiology* we shall acquire much necessary knowledge regarding the action and uses of the parts or organs, and the various life processes by which the strength and health of the body are maintained.

These two subjects are so closely related to each other that they are generally studied together as essentially one and the same branch of knowledge.

2. Man as an Animal.—So far as regards his physical structure, that is, the composition of his body and the action of his organs of life and motion, man is essentially an animal. But of all animals he is the highest type—the most complex in organization, the most perfect in adaptation to his environment. The points of resemblance between him and the lower animals are striking and numerous.

If we classify him with those whose physical structure is nearest like his own, we shall place him in the great sub-kingdom of *vertebrates*, or backboned animals, and in the group called *mammals*, which includes all those vertebrates whose young derive their sustenance from their mother's milk. But man resembles some mammals much more closely than others; and hence if we classify him still more exactly, we shall place him with monkeys and apes in that division of mammals

usually known as *primates*—a division which represents the most perfect of all animal structures.

Why thus include man in the same class with apes and monkeys? In his physical conformation he is certainly vastly superior to the highest type of apes, and this fact has led many naturalists to ask why he should not be classed in a distinct zoölogical order by himself. But Professor Huxley and others who have devoted the most careful attention to this subject, have arrived at the conclusion that, after all, the anatomical differences between man and the higher apes are not greater than those which separate these man-resembling apes from apes lower in the scale of existence. And as naturalists are agreed in placing both the lower and the higher apes in the order of primates, there seems to be no good reason why man should not be placed there also.

3. Man's Superiority.—Although the human body resembles the bodies of lower animals in so many respects, it differs from them in various important features, and possesses numerous peculiarities of structure that are distinctively human and not found in any of the lower animals. These peculiarities in every case contribute to man's superiority.

In the first place, man is the only animal that can stand and walk erect — that is, with the spinal column at right angles with the earth's surface, and in a direct line with the head and legs. The parts of his body are so perfectly adjusted that he can continue in this attitude without apparent effort and without fatigue. While the lower limbs suffice for support and locomotion, the upper limbs are left free for the performance of other functions which to inferior animals

are impossible or at best imperfect. The head is so perfectly balanced on the top of the spinal column as to place the face and eyes exactly to the front. The hands are so constructed as to adapt them to all kinds of work, from that requiring the lightest and most skillful touch to that involving the exercise of great strength or ingenuity. These are some of the most readily apparent and most important differences between man and even the highest of the lower animals.

FIG. 1.

Let us observe some of the advantages which man derives from his habitually erect position in standing and walking. The diagram (Fig. 1), shown in the margin, illustrates the position of the principal parts of his body with respect to one another and also with respect to the earth on which he stands. The line which marks the center of gravity when his body is in an erect position, coincides almost exactly with the spinal column. In all other backboned animals the position of these parts is markedly different. In some, as birds and apes, (Figs. 2 and 3), the spinal column is in an oblique position with reference both to the center of gravity and the earth's surface. In most four-footed animals (as in Fig. 4) it is at right angles with the line of support and nearly horizontal. The hip and knee joints are bent at angles more or less

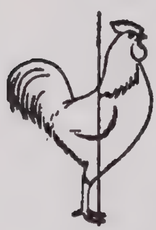


FIG. 2.

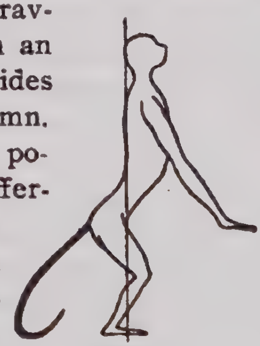


FIG. 3.

acute; and the upper or forward limbs are intended for support or progression, and are therefore unfitted for other purposes. The inconvenience and inferiority of such positions when compared with the erect carriage and freedom of movement which characterize the human body are clearly apparent.

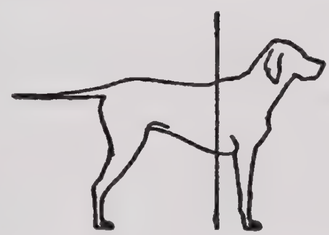


Fig. 4.

In the ape, which has a body the most nearly like that of man, there are still other differences both in the position of the trunk and head and in their general contour and relative proportion. The ape's skull is smaller, its arms are longer, its legs are proportionately shorter than those of man. The greatest difference exists in the comparative size and organization of the brain. While the weight of man's brain is hardly ever less than forty-two ounces, the brain of a gorilla, which is a much larger animal, seldom weighs more than twenty ounces.

4. **Man's True Place in Nature** may be briefly summed up and described as follows: He belongs (1) to the animal kingdom; (2) to the sub-kingdom of vertebrates or backboned animals; (3) to the class of vertebrates called mammalia; (4) to the order of mammalia known as primates. While in many respects he bears a close resemblance to lower animals, the general structure of his body is such as fits him to occupy the highest place in the scale of life upon the earth. Of these latter characteristics we shall learn many particulars as we continue the study of this subject.

II.—PRELIMINARY DEFINITIONS.

5. **The Body Composed of Parts.**—The most ignorant observer will not have failed to notice that the human body is composed of several related parts, each of which has its own offices or functions to perform. The most obvious of these parts are the head, the trunk, the legs, the arms; and these, taken together, comprise the entire body. There are also many minor parts, subdivisions of these major parts, such as the face, the eyes, the ears, the nose, the mouth, the hands, the fingers, the feet, the toes. The body has sometimes been compared to a house with various floors and passages, with doors and windows, and with all the appurtenances and appliances necessary to the comfort and health of its inhabitant.

6. **The Body Composed of Various Materials.**—As a dwelling house is built of various materials,—such as wood, stone, brick, mortar, glass,—so also is the body made up of several different substances forming the bones, the flesh, the blood, the skin, the hair, and various other structures and tissues. Continuing the comparison still further, we shall find that, as in a dwelling house there are various arrangements for providing its inmates with heat, air, light, and food, so also in the human house which we call the body, there are organs or sets of organs designed for the performance of specific duties necessary to the life of its occupant.

7. **Definitions.**—The foregoing observations and

comparisons lead us to the following definitions which we must necessarily understand before proceeding to a study of the human body in detail.

(1) *Tissues.* The materials of which the different parts or organs are composed are called *tissues.* Thus the bones are composed chiefly of osseous tissue; the muscles of muscular tissue; the ligaments of connective tissue.

(2) *Organs.* An *organ* is a certain part or structure of the body, composed of one or more tissues and designed to aid in carrying on some action essential to the well-being of the whole. The heart, the lungs, the stomach, are organs.

(3) *System.* A combination or assemblage of parts composed of the same or similar tissues is called a *system.* The bones, taken together, comprise the osseous system; the muscles, the muscular system; the skin and its appendages, the tegumentary system.

The word *system* is also applied in a wider sense to a concurrence of parts or organs in the performance of some particular function. We speak, therefore, of the digestive system, the respiratory system, the circulatory system, each of which includes several organs, or parts, and is made up of widely dissimilar tissues.

In a third and still broader sense, the word *system* is used to indicate the entire body as a physiological or an anatomical whole, as when we say, "The system needs exercise," or, "His system is exhausted."

(4) *Function.* The particular office or action performed by an organ or any distinct part of the body, is called its *function.* Thus the function of the teeth is to masticate the food; one function of the bones is to protect different parts of the body; the function of the heart is to promote the circulation of the blood.

III.—THE CONSTRUCTION OF THE BODY.

8. Tissues of the Body.—It has just been said that the body is made up of various tissues. Let us examine into this matter a little more closely. We do not have to go to books to learn that the constituent substances of the body are some of them solids, and some of them fluids. Of the solids, the most familiar examples are the bones, the teeth, the hair; of the fluids, the most abundant is the blood.

All the tissues are solids; but it must not be supposed that any tissue exists wholly separate from other tissues. For example, the bones are composed essentially of *osseous tissue*, but in every living bone there are other tissues which are necessary to its growth and strength. Muscles are composed mainly of *muscular tissue*, and yet in every muscle there are blood vessels, lymph vessels, and connective tissue and nervous tissue.

9. Appearance of the Tissues.—By carefully observing the various structures that compose the living body, we shall learn not only to distinguish the different tissues, one from another, but to understand the functions which each performs in the animal economy. We perceive that osseous tissue and cartilaginous tissue resemble each other in being arranged in compact masses; but the latter differs from the former in being softer, whiter, and generally more elastic. Other tissues, as the muscular and the nervous, are

composed of threads or fibers arranged in various ways; others, as the mucous, the membraneous, and the serous, are spread out in thin membranes upon the surface of certain parts or organs; still others, as those composing the blood vessels, are arranged so as to form tubes or vessels for the passage of the liquids of the body. Thus the more deeply we enter into the study of this subject, the greater does the complexity of the body's construction appear to be.

10. Composition of the Tissues.—Now having learned that the solid portions of the body are composed of tissues variously constructed and differing greatly in appearance, let us go a step further in our inquiries and ask, of what are the tissues themselves composed? If they were merely dead matter it would be easy, through the aid of chemical analysis, to answer this question by naming the elements into which they may be resolved; and there the investigation would end. But the tissues are not dead matter. They are parts of a living body and as such they are capable of growing, of nourishing themselves, and of maintaining for a limited time their structural perfection. And so we must study them not as dead matter, nor simply as chemical elements existing in certain definite combinations, but as forms of matter exhibiting the phenomena of life and depending upon the operations of the laws of life for their existence.

11. Cells.—All the tissues of the body are composed of *cells* or of material derived from cells. A cell is the simplest form of organized living matter. All plants, as well as all animals, originate from a primary cell which, by division into other cells and by differentiation in form and composition, produces the various tissues.

A typical cell is a minute vesicle, visible only under the microscope, and of a viscous or jelly-like consistency (Fig. 5). It is more or less granular in appearance, like a sheet of ground glass, and generally contains in its center a minute oval body called a *nucleus*. The nucleus in turn often contains one or more still smaller bodies called *nucleoli*.

FIG. 5.—A cell, very highly magnified.

12. To the cell in its ultimate manifestation as the physical basis of life, the name *protoplasm* (from Greek *protos*, first, *plasma*, anything formed) is applied. Protoplasm, wherever it exists, is composed chemically of four elements, carbon, oxygen, hydrogen, and nitrogen, united in extremely complex and unstable molecular combinations.

In some of the lowest animal and vegetable forms a single cell constitutes the entire individual; these are said to be *protoplasmic*. Others consist of two or more cells; and, generally, those highest in the scale of existence possess organisms the most complex. It is by the multiplication and differentiation of cells that the various forms of life are produced.

13. Cells have the power of taking in materials from the medium which surrounds them. They are also capable of selecting nutriment and converting it into their own substance. It is therefore in these minute cells that the nutrition of the body takes place. Single cells, by dividing and subdividing, may form numerous independent cells, each having its own life (Fig. 6). It is by their increase in size and number that the growth of the body is effected. Under

FIG. 6.—Showing how a cell may divide and form two cells.

stimulation certain cells have the power of motion or contractility; other cells have other powers, such as the secretion of liquids, or the transmission of sensation.

Not only are all the tissues, or solid parts of the living body, composed of cells, but many of the fluids also have cells, or other solid particles, suspended in them. This is particularly true of the fluids that are concerned in the nutritive processes, such as the blood and the lymph.

14. Each cell has its own independent life. Some exist but a brief period; others live for years. The changes that are constantly going on in the body are the results of changes in the protoplasmic material of its cells—changes which affect the growth of the cells, their multiplication, their breaking down, their removal. So long as the formation of the cells goes on more rapidly than their breaking down, the body grows, or increases in size. When the breaking down process is just equal to the process of construction, growth ceases and there is little if any change in the bulk or strength of the tissues. When the cells partially lose their power of multiplication or construction, the breaking down process exceeds the accumulation of new matter, and decay of strength and vitality is the result.

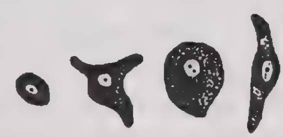


FIG. 7.—Various forms of cells.

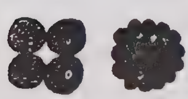


FIG. 8. Groups of cells, highly magnified.

15. Chemical Composition of the Body.—We have spoken of the body as composed of parts which the most illiterate person can distinguish (§ 5); we have

seen that these parts are made up of organs or systems of organs designed for the performance of definite functions; we have learned that these organs are composed of tissues of many different varieties; and finally we have discovered that the tissues are aggregations of minute cells, the simplest forms of organized living matter, which we may describe as being individuated masses of protoplasm. Thus far we have regarded the body as being animated or possessing life; but let us think of it now under another aspect irrespective of the phenomena of life, and we shall find that it is an aggregation of variously combined chemical elements. Indeed, all material objects, all substances of which we have any knowledge, are composed of one or more of such elements.

16. We have already said, (§ 12), that four elements, carbon, oxgen, hydrogen, and nitrogen, are the necessary constituents of protoplasm. These, combined with numerous other elements, constitute the entire material of the human body. As would naturally be supposed, some of the tissues contain certain elements in much larger proportions than do others: for instance, in the bones, or osseous tissue, we find large quantities of calcium; in the hair and nails sulphur exists in combination with other elements; of the blood, iron is one of the peculiar constituents. Besides these elements there are others in the various tissues, as phosphorus, magnesium, sodium, potassium, chlorine, fluorine, manganese, and perhaps two or three more.

17. The following table shows the average proportion in which the various elements usually exist in the human body:

Elements.	Parts in 1000	Elements.	Parts in 1000
Oxygen	720.	Chlorine	.85
Carbon	135.	Fluorine	.80
Hydrogen	91.	Potassium	.26
Nitrogen	25.	Iron	.10
Phosphorus	11.5	Magnesium	.012
Calcium	13.	Silicon	.002
Sulphur	1.476	Manganese	merely a trace.
Sodium	1.		

But it must not be supposed for a moment that these elements are found in a free or separate state. Oxygen and hydrogen exist in combination with each other in the form of water. Oxygen is also combined variously with other elements, thus forming many compound inorganic salts, such as carbonate of lime (which is composed of carbon, oxygen, and calcium) and sulphate of potash (sulphur, oxygen, and potassium). These substances enter into the composition of certain portions of the body, as the bones, the teeth, etc. Other combinations of elements compose other tissues or structures.

18. We shall presently learn that the different tissues are nourished and sustained by the food which is eaten. Now it will be plain to you that no substance can give nourishment to any tissue unless it contains at least one of the elements composing that tissue. The bones must have calcium or lime; the hair and nails must be supplied with the requisite proportion of sulphur; the blood must have its modicum of iron; and each part of the body must receive its due supply of the elements which enter into its structure.

The foregoing are a few foundation facts, the remembrance of which will help you later on to a clearer

understanding of many of the principles of anatomy and physiology.

19. Practical Questions.—Name some of the different sciences which have man for their subject. How many and which of these sciences have also the ape or the horse for their subject?

From your answers to these two questions deduce an answer to this: In what respect is man wholly different from other animals?

Why do we say man is an animal of the highest type? Why is he classified with apes?

What are the advantages of the erect position in standing and walking? Although apes sometimes walk or stand erect, in what respects are their bodies not adapted to an upright position?

How may the body be compared to a house? In what particular respect does this analogy fail to hold good?

Name the functions of the hands; of the teeth; of the eyes; of the feet.

What is the minutest, and so far as we know, the ultimate form of organized living matter? What action takes place when a muscular cell is stimulated?

Does the duration of life of a cell differ from that of the body in which it occurs? In what particular respect does youth differ from adolescence, or middle age? In what respect from old age? Explain why.

If a person could wholly avoid accidents and escape disease would he live always? Why not?

Name the four most important inorganic elements found in the body. How many chemical elements enter into the composition of the various tissues?

In what tissues does lime exist; sulphur?

IV.—OSSEOUS TISSUE.

20. The Body a House.—The body has already been compared to a house with its various rooms and passages, its doors and windows, and its numerous appurtenances and appliances for the comfort of its occupant. We have begun a careful study of that house and wish to examine the details of its construction. We have already considered briefly its outside appearance, and we have observed in a general way the nature of the material which enters into the composition of its parts. As in observing the structure of a common house it is useful for one to know at the outset what is meant by certain expressions, as floors, ceilings, wainscoting, mortar, and brick, so also in the study of the human house it has been necessary for us to learn the meanings of such terms as system, organs, tissues, and other names and words which we shall constantly use as we proceed.

Wishing now to make a somewhat detailed observation of the parts of the house, our first inquiry is with reference to its framework, for upon that framework depend the shape, the strength, and the general appearance of the entire structure.

21. The Framework of the Body.—What is the framework of the human body? No intelligent person will need to be told that it is the bones, so arranged and joined together as to form the structure commonly called the *skeleton*. The material of which this framework is chiefly composed is *osseous tissue*.

22. Appearance of Bone.—The common name for osseous tissue is *bone*. Like the other tissues it is composed, in the living organism, of minute cells having the character and properties possessed by all cells. If you could see live bone as it really exists in the body, you would perceive that it is not exactly like the white, inanimate substance, called bone, which is picked up from the ground or taken from a joint of beef on the table. When all the cells are alive and actively at work, when the blood vessels and other tissues which help to compose the living bone are present in their natural order and arrangement, bone has an appearance quite different from that which it takes on in the dried skeleton. Dead bone,—the kind that we usually see,—is of a uniformly white color. Live bone,—the bone in the living body,—is pinkish white on the surface, varying to a deep red near its center.

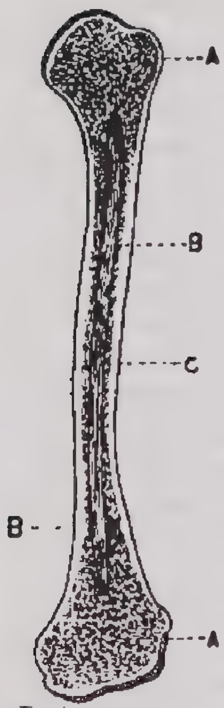


FIG. 4. SECTION OF A BONE.

A.—Cancellous osseous tissue.
B.—Compact osseous tissue.
C.—Medullary space (§ 25).

23. Structure of Bone.—Osseous tissue,—that is, the true bony substance,—is one of the hardest substances in the body. It is also more or less tough and elastic. It is not everywhere the same.

Experiment:—Take any bone, as that from a joint of beef. Saw through the middle of it and examine the section closely. You will see that the tissue composing

one part of it appears to be quite different from that composing the other part (Fig. 9). The outside part is dense and compact; the inside is more porous and consists of slender fibers arranged in the form of lattice work. The former we call *compact osseous tissue;* the latter we call *cancellous osseous tissue* (from Latin *cancelli*, lattice work). It is also sometimes called *spongy tissue* on account of its porous character.

These two varieties of osseous tissue exist in different proportions in all the bones. Where most strength is desirable, the compact tissue predominates; where lightness is requisite and great strength not so necessary, the bone is composed chiefly of cancellous tissue.

24. The Periosteum.—The live bone is enclosed in a strong fibrous tissue called the *periosteum* (Fig. 10). The periosteum covers the bone completely except at those points where it forms joints with other bones. It consists of two layers closely united together. Where tendons or ligaments are attached to the bone they are incorporated with it. The periosteum is everywhere traversed by a network of small blood vessels which supply nourishment to the bone.

FIG. 10.—A Bone, showing the periosteum partly removed.

The importance of the periosteum in protecting and in promoting the growth of the bone which it encloses is very great. In some cases parts of bones have been removed leaving the periosteum uninjured, and new bone has been formed in place of that removed. But if the periosteum itself be removed or injured, the bone loses its vitality and dies.

25. The Marrow.—The shafts of the long bones contain a cylindrical cavity, or hollow, in which is a sub-

stance called *marrow* (Fig. 9). The marrow fills not only these cavities, called *medullary spaces*, but also the spaces in the cancellated or spongy tissue of all the bones. Marrow is of two kinds—red and yellow. The *red marrow* is found in the cancellated tissue of the short and irregular bones. It consists of numerous minute cells of a roundish nucleated form, and many small blood-vessels; and it contains but very little fat. The *yellow marrow* fills completely the medullary spaces of the long bones, and is also found in the cancellated tissue of others. It is composed almost wholly of fat. Very little is known as to the functions of the marrow, but it is probably of much value in the nutrition of bone.

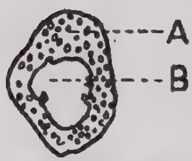


FIG. 11.—CROSS SECTION OF LONG BONE.
A.—Compact tissue.
B.—Medullary canal.

26. The bones are all well supplied with blood-vessels. These are arranged chiefly as a dense network of minute tubes traversing the periosteum and penetrating the osseous tissue. Nerves also are distributed to the periosteum and thence extend into the interior of the bone.

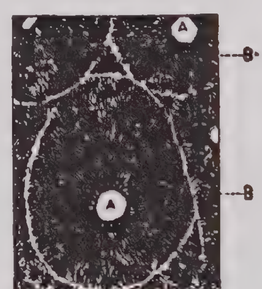


FIG. 12.—CROSS SECTION OF A THIN SLICE OF BONE HIGHLY MAGNIFIED.
A.—Haversian canals.
B, B.—Lacunæ.

27. Microscopic Structure of Bone.—Examine a section of a long bone under the microscope. Observe particularly the compact tissue and also the wall of the medullary space. You will see that they are full of minute orifices. These orifices are the mouths of

exceedingly small tubular passages or canals which traverse the compact tissue of the bone.

These canals are cylindrical in form and from 1-1000 to 1-200 of an inch in diameter. They are connected in such a manner as to fill the osseous tissue with a complete network of canals. They are called *Haversian canals*, from the name of their discoverer, and are channels for the passage of the minute blood and lymphatic vessels that are supplied to the bones. Encircling each Haversian canal as a center, are to be seen numerous thin plates of bone tissue. These thin plates of bone when in their natural position may be compared "to a number of sheets of paper pasted one after another around a central hollow cylinder." Between these plates of bone, which are called *lamellæ*, are numerous dark specks connected with each other and with the Haversian canal by fine lines. These dark specks are called *lacunæ*. During life they are each filled with a cell or cells whose function is to bring nutrition into contact with the true bony tissue. (Fig. 14.)

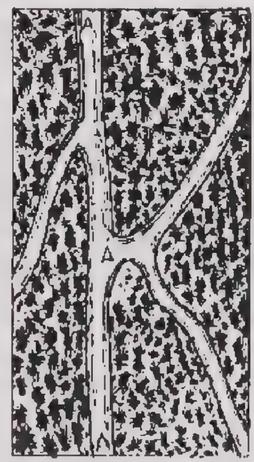


FIG. 13.
LONGITUDINAL SECTION OF BONE HIGHLY MAGNIFIED.
A, A.—Haversian canals.

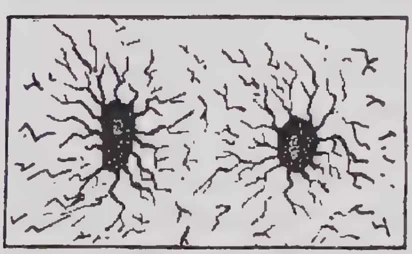


FIG. 14.—BONE CELLS.

28. Chemical Composition of Bone.—Bone is composed

of earthy, or inorganic matter, and animal, or organic matter, intimately combined together. These constituents exist in different proportions at different periods of life; but generally speaking, a bone contains two parts of earthy matter to one part of animal matter. The animal matter gives the bone its elasticity and toughness; the earthy matter, which is chiefly phosphate of lime, gives it its hardness.

In childhood there is a much larger proportion of the animal matter, and hence the bones are more pliant and not so easily broken. But in old age the earthy is in excess and the quantity of the animal matter is deficient; hence the bones of elderly people are more brittle and easily broken.

FIG. 15.—Bone from which the earthy matter has been removed, tied in a knot.

Experiment:—Here is a common but nevertheless interesting experiment. Take a long, slender bone and immerse it in diluted muriatic acid. In a short time it will become flexible, bending easily in every direction. It may even be tied in a knot (Fig. 15). Why is this? The acid has dissolved and removed the mineral part and left only the animal part, but it has done this without changing the form of the bone.

Try now the opposite experiment. Take another bone and put it in a hot fire. The animal matter will be burned out and only the earthy matter will remain. If carefully handled, its shape will not be changed, but it will lose weight and become so brittle that you can crumble it between your fingers. Now try each of these experiments again, weighing the bone care-

fully both before and after. How much weight does it lose each time? What proportion is this of the whole weight? What do you learn from this?

In order that the bones may keep their shape and be strong, it is important that the proportion of animal to earthy matter should remain about as has been learned from these experiments. Somewhat more than half the bone by weight is phosphate of lime. Then there is of carbonate of lime, one tenth, besides three or four other substances in smaller quantities. About one third of the bone,—the animal matter,—is composed of organic substances, gelatin, and blood vessels.

FIG. 16.—Cross section of long bone from which the earthy matter has been removed.

29. Review Questions.—Name some substances besides osseous tissue which enter into the composition of the bones.

Why is it necessary that the bones should be slightly elastic?

Which are the more elastic, the bones of a child, or those of an aged person? Why is this so?

Why should not children be encouraged to walk very early? Why should they not be required to carry heavy burdens?

Why is it that children are often uninjured by falls which would be disastrous to old people?

Why is the periosteum supplied with so many blood vessels? Are there any blood vessels in the bones?

Of what use are the bone cells? What is meant by the true bony tissue?

V.—CARTILAGE.

30. Appearance of Cartilage.—In various parts of the body, but chiefly connected with the bones, there is a peculiar substance called *cartilage.* In some respects it resembles bone; but it is softer, whiter, more elastic, and more pliant. In color it is pale bluish-white; but when cut in thin slices it appears quite transparent. Cartilage has so many resemblances to bone that it is sometimes described as bony matter in a state of preparation, and yet true cartilaginous tissue differs in some very important respects from osseous tissue.

Cartilage is enclosed in a tough membraneous tissue called the *perichondrium*, which is very much like the periosteum that invests the bones. The cartilages serve an important part in the framework of the body, and are indispensable adjuncts to the bony skeleton.

31. Ossification.—In infants very many parts of the skeleton, which afterwards become bone, consist of cartilage. Gradually the cartilage cells enlarge and arrange themselves in rows, becoming farther and farther separated. Meanwhile there is constantly going on a deposit of earthy matter between them. After a time the cartilage cells disappear, and true osseous tissue is formed. This change is called *ossification* and is a very complicated process.

Some parts of the body remain in the cartilage state during the whole period of life. For instance, the parts of a bone where it unites with another, forming

a movable joint, are always covered with cartilage. The ribs are connected with the breastbone by means of cartilages. Cartilage performs also an important function in the walls of various passages which require to be kept open—such as the windpipe, the nostrils, the ears.

32. **Varieties of Cartilage.**—There are several varieties of cartilage differing from *true* or *hyaline cartilage*, the kind we have just described, both in appearance and in functions. One variety called *yellow* or *elastic cartilage* is found in the outer ear, in the epiglottis and elsewhere, and contains numerous interlacing elastic fibres. Another, called *fibro cartilage*, has much the same functions as common connective tissue.

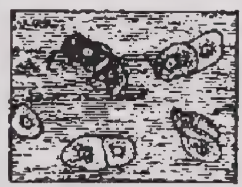


FIG. 17.—CARTILAGE CELLS.

33. There are but few blood vessels in cartilage, except that wherein ossification is taking place. In old age, by the deposit in them of lime salts, many of the cartilages become hardened, but not changed to bone, depriving the body's framework of much of its elasticity and ease of movement.

34. **Ankylosis.**—In early life many of the bones which are afterward only a single piece, are composed of two or more distinct parts united only by cartilage. For example, the sternum or breastbone in childhood consists of five separate pieces; but in later life these grow together and form but a single bone. This process of the union of two or more bones into one is called *ankylosis*. Sometimes ankylosis may occur in a joint; the bones composing the joint unite to form apparently one bone, and the joint then becomes immovable.

VI.—STRUCTURE OF THE SKELETON.

35. **What is the Skeleton?**—As the framework of a house not only consists of posts, beams, and girders, but also includes mechanisms or appliances which bind the different parts together, so too the framework of the human body comprises besides the bones, both the cartilages and the ligamentous tissues which are essential to its completeness. The word *skeleton* in its broadest sense has reference to this framework in its entirety as it exists in the living body; but in its restricted and more common meaning it relates only to the bones arranged in their natural positions.

In our study of this subject it will be better if we think of the skeleton not as mere senseless, dead material, but as a vital organ each part of which has its own special function to perform. It consists, in the adult human being, of two hundred distinct bones, together with the ligamentous and cartilagineous tissues which bind them together or otherwise aid in perfecting its structure.

The bones of the skeleton serve as a basis for the attachment of the muscles, they give support to the softer parts of the body, and they form a protection for many of the more delicate organs. The skeleton is therefore something more than a mere framework.

36. **Shapes of the Bones.**—It is interesting to observe the perfectness of the skeleton taken as a whole. This

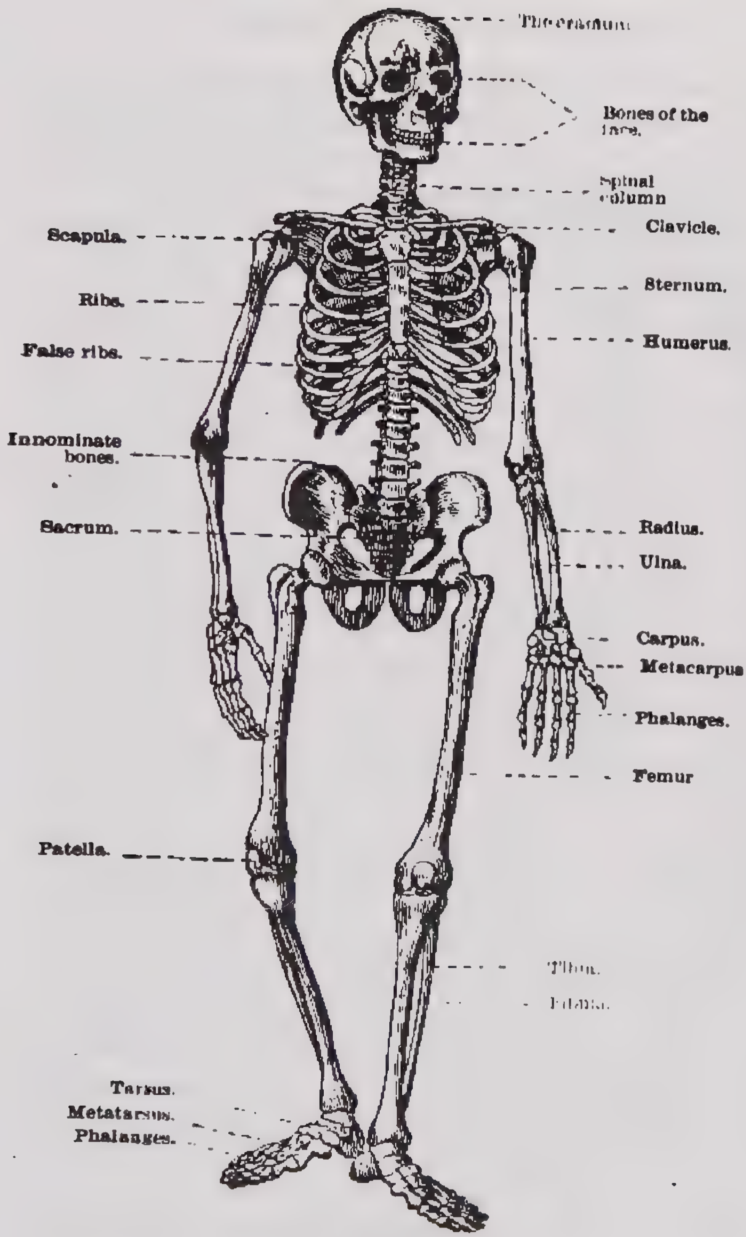


FIG. 18.—THE SKELETON.

is the result of the arrangement of its parts, each of which is perfectly adapted to its own place and to the performance of its own special functions. A superficial observation of our own arms and hands, heads and faces, teaches us that the bones must be of different lengths and of various shapes — that some are long, some short, some flat, and some irregular in form.

FIG. 19.—LONG BONES.
A, B.—Enlarged extremities.

37. Examples of the *long bones* are those of the arms and legs. The ribs are also long bones. A study of a long bone of some animal will help us to understand the peculiarities of their structure. Each long bone consists of a *shaft* and two enlarged *extremities* affording space for the thicker portions of the muscles which lie around it. (Fig. 19). The enlarged extremities of such bones are generally irregular forms, or *processes*, for the purpose of articulation with other bones to which they are joined; and they present various protuberances and flattened surfaces for the attachment of muscles and tendons. The walls of the shaft consist of dense compact tissue, thicker in the center and becoming gradually thinner toward the extremities. This arrangement imparts great strength to the bone.

The extremities are composed chiefly of spongy or

cancellated tissue covered with a thin layer of compact osseous tissue. This gives lightness to the bone where great extent of surface is necessary and strength not so important (Fig. 9).

FIG. 20.—SHORT BONES AND LONG BONES. The Foot.

The hollow interior of the shaft is filled with *medulla* or *marrow*. The long bones are not perfectly straight, but are curved generally in two directions. This adds to their elasticity and also in certain instances gives them greater strength.

38. The *short bones* are found in those parts of the skeleton where strength is required, but where motion is limited. In many cases, as in the hand and the foot, several of these bones are firmly bound together by muscles and ligaments (Fig. 20). The short bones are composed chiefly of spongy tissue, with only a thin layer of compact substance on the surface.

39. The *flat bones* occur in those parts of the body where there are important organs to be protected or where broad surfaces are necessary for the attachment of the muscles. These bones consist of compact tissue with spongy tissue of varying thickness in the interior. The bones of the cranium are of this class.

40. The *irregular bones* are of various shapes and serve widely different purposes. In composition they are similar to the other bones, being more compact in situations where great strength is necessary, and having a spongy or porous character where lightness and extent of surface are essential (Fig. 22).

41. Questions. — If the bones of one's body were composed of one third mineral matter and two thirds

animal matter, what might be some of the results? Why?

If the long bones were solid throughout instead of hollow, what would be the result? What part of a long bone requires to be very strong? Why?

Which is stronger, a hollow cylinder or a solid rod made of the same substance and containing the same amount of material? Apply this principle to the hollow long bones, and explain why they are superior to solid bones having equal weight.

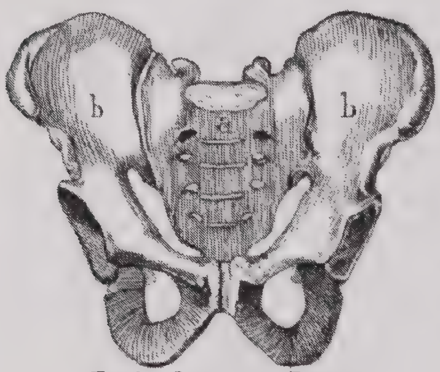


FIG. 21.—IRREGULAR BONES.
a.—The sacrum.
b.—The innominate bones.

Name some parts of the body where short bones occur. Name one part of the skeleton that is made up chiefly of irregular bones.

Where are some of the flat bones? What parts do they protect? Name some inconveniences that might occur if all the bones were flat. What advantage results from there being, instead of a single large bone, several small bones firmly bound together in the foot?

What kind of bones are those in the fingers?

Which bone or assemblage of bones is the most important part of the framework of the body?

The name skeleton is from the Greek word *skeletos*, meaning dried, or dried up. To what, may we suppose, was the word orginally applied—to dead bones, or to living bones?

VII.—THE TRUNK.

42. The larger part of the human body is called the *trunk.* Often the trunk alone is called the body. In life the bones and other tissues of the trunk enclose two great cavities, the chest or thorax and the abdomen. The skeleton of the trunk consists of the spinal column, the ribs, and the sternum or breastbone.

43. **The Spinal Column.**—The spinal column may be compared to the main pillar or support of a house. All other parts of the framework depend, more or less directly, upon it. Its common name is the backbone. It is not a single bone, however, but consists of thirty-three irregular bones placed one on another so as to form a flexible column.

Take thirty-three empty spools about the same size. Set them on end, one upon another. Run a cord through them. You have now a rude representation of the backbone with its component pieces.

The thirty-three bones of the spinal column are called *vertebræ.* Twenty-four of these are separate throughout life. Five are united to form a single bone, the sacrum, and four are united to form another bone, the coccyx. In adult life, therefore, the spinal column really consists of only twenty-six separate bones. The vertebræ are named according to their location. There are seven cervical vertebræ, twelve dorsal, five lumbar, five sacral, and four coccygeal.

Each vertebra consists of two parts, a body and an

arch, and these enclose a ring and have certain notches and processes upon their surfaces. The *body* of the vertebra is its front part. Each body is connected, by means of cartilages and ligaments, with the bodies of the vertebræ above and below it. The *arch* springs from the back of the body, and is composed of two symmetrical halves, each half consisting of an anterior part or *pedicle* and a posterior part or *lamina*. Enclosed by the body of the vertebra and the two laminæ is the ring or *spinal foramen*, which serves for the passage and protection of the spinal cord. The rings, as they lie one upon another in the entire spinal column, form a long cylindrical passage called the *spinal canal*. Projecting backward from the lamina of each arch are rough projections called *spinous processes;* these impart to the entire column that rough and spiny character which has given to it the name *spine* (from Latin *spina*, a thorn).

FIG. 22.—SIDE VIEW OF A VERTEBRA.
A.—The body of the vertebra.
B.—Transverse process.
C.—Spinous process.

FIG. 23.—A VERTEBRA (viewed from above).
a.—The body of the vertebra.
b.—Spinal foramen.
c, c, c.—Processes.

44. At the lower end of the spinal column is a large,

wedge-shaped bone called the *sacrum*. This bone is composed of five orginally separate vertebræ fused together, or ankylosed, so as to form but a single bone. Below the sacrum is the *coccyx*, usually formed of four small segments of bone or vertebræ. The uppermost one of these segments is firmly attached to the lower end of the sacrum. As age advances the segments become united and form a single bone.

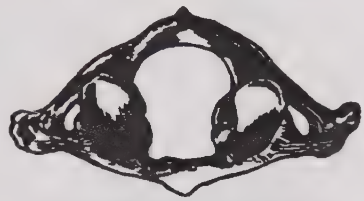


FIG. 24.—THE ATLAS (upper side).

45. The vertebra at the upper end of the spinal column is called the *atlas* (Fig. 24). It differs from other vertebræ in several respects: it has no body and no spinous processes; its ring is very large, and on each side of the ring is a thick mass of bone by which it is articulated with the lowermost bone of the skull. The vertebra next below the atlas has also a peculiar form, being furnished with a tooth-like process or pivot upon which the atlas turns. This is called the *axis* (Fig. 25). The peculiar structure and articulation of these bones give to the head great freedom of movement, especially in a lateral direction.

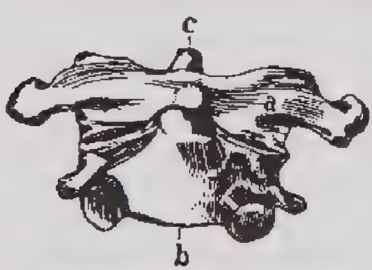


FIG. 25.—a, atlas; b, axis; c, pivot of the axis.

46. General Aspects of the Spine.—Let us now observe the spine in its general aspects. Its average length in adults is about twenty-seven inches. Its widest part

is at the base of the sacrum. From this point upward it diminishes in breadth quite gradually, but downward it tapers more rapidly until it ends in the tip of the coccyx. Viewed from either side it has two series of curves, backward and forward and again backward and forward. It has also a slight lateral curvature, directed generally toward the right side. It is the great column of support for the body. It bears the weight of the trunk, the upper limbs, and the head. It makes it possible for the body to maintain an erect position. Its numerous spinous processes serve for the attachment of many important muscles which are of use in controlling the movements of the body. The vertebræ, although resting one upon another, are separated by layers of elastic cartilage. These serve as cushions and aid greatly in making every movement of the spinal column easy and free from shocks or friction.

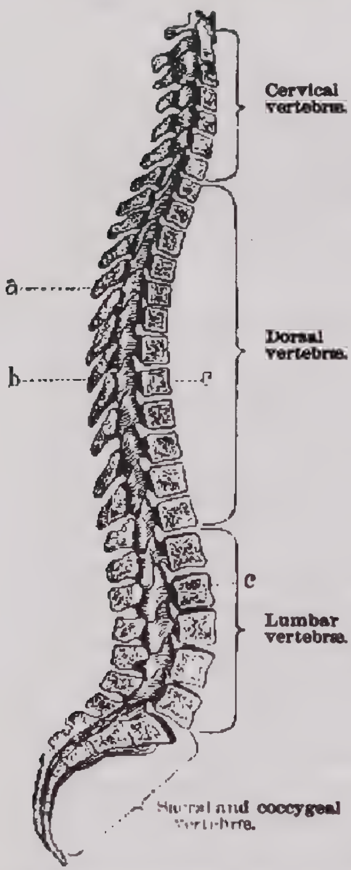


FIG. 26.—LONGITUDINAL SECTION OF THE SPINAL COLUMN.
a, b —Spinous processes.
c, c.—Bodies of vertebræ.

47. The Thorax.—In front of the upper half of

the spinal column there extends a cage-like enclosure formed of bones and cartilages. It is conical in shape, having its apex above. The twelve dorsal vertebræ of the spinal column form the middle part of its posterior wall; there are twelve ribs with their corresponding cartilages on each side; and in front is a flat bone called the sternum or breastbone. This enclosure is called the *thorax;* and it forms a cavity for the inclusion and protection of the principal organs of respiration and circulation (Fig. 27).

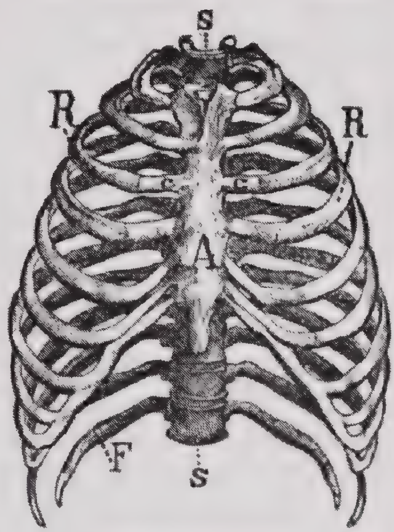


FIG. 27.—THE THORAX.
S, S.—Part of the spinal column.
R, R.—Ribs.
A.—The sternum.
c, c.—Costal cartilages.
F.—Floating rib.

48. The Ribs.—There are twenty-four *ribs*, twelve on each side of the thorax. All these ribs are connected behind with the spinal column. The upper seven on each side are also connected in front, by means of costal cartilages, with the sternum. These seven ribs are called the *true ribs*. The remaining five do not reach the sternum and are called *false ribs*. Three of these are joined to each other by costal cartilage, which also connects them with the seventh true rib. The two lowest, being entirely free in front, are called *floating ribs*.

49. Costal Cartilages.—The costal cartilages are

elastic structures, softer than bone, which serve to prolong the ribs toward the front part of the thorax. Both the ribs and the costal cartilages vary in their length, breadth, and direction. The first and second costal cartilages lie in almost a horizontal position; all the others incline upward and inward.

FIG. 28.—Lateral view of the sternum.

50. The Sternum.—The sternum is a flat bone which forms the central part of the front wall of the thorax. It is commonly called the breastbone. In the adult it consists of three portions very closely united together. When viewed from the front its shape is somewhat like that of a broad dagger or ancient broadsword.

FIG. 29.—Front view of the sternum.

Two other bones, the *clavicles* or *collar-bones*, are connected with the sternum near its upper end, just above the first ribs, one on each side of the body. The clavicles, however, are not classified with the bones of the trunk, but belong to the upper extremities.

51. The Trunk as a Whole.—How many vertebræ are included in the spinal column? How many and what bones, besides the twelve vertebræ, help to enclose the cavity of the thorax?

How many of the ribs are connected with the sternum? Are they joined directly to it?

What kinds of bones are most numerous in the trunk?

What is the total number of bones in this part of the body? Make a classified list of these bones.

VIII.—THE SKULL.

52. The *skull* is the name applied to the skeleton of the head. The bones of the head and trunk taken together comprise what is called the *axial skeleton*.

Upon which of the vertebræ of the spinal column does the skull rest?

We might regard the skull as an expansion of the spinal column at its upper extremity. We might say that this expansion is composed of vertebræ very closely connected and so arranged as to enclose the brain and the organs of special sense. The more common method of describing this part, however, is to consider the skull as being composed of two parts—the *cranium* and the *face*.

53. The Cranium.—The cranium consists of eight flattened irregular bones:

1. The *occipital* bone, which is at the back part and base of the head, and rests upon the atlas, or first vertebra of the spinal column;

2.-3. Two *parietal* bones, which form the sides and roof of the skull, and like strong walls protect the brain from injury;

4. The *frontal* bone, which is set at the front part of the head and forms the forehead;

5.-6. Two *temporal* bones, which are situated at the side and base of the skull;

7. The *sphenoid* bone, which lies near the front part of the base of the cranium, and being connected with all the other cranial bones binds them firmly together;

8. The *ethmoid* bone, which is a very porous bone of a cubical shape, situated at the front part of the base of the cranium.

These bones are so joined together by their edges as to form a bony case enclosing a cavity called the cranial cavity. In this cavity is the brain.

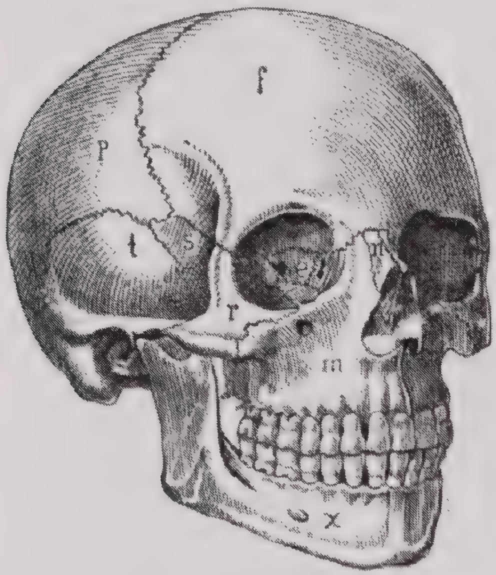


FIG. 30.—THE SKULL.

p, parietal; f, frontal; t, temporal; s, sphenoid; e, ethmoid; n, nasal; m, superior maxillary; x, inferior maxillary; r, malar.

54. Notice the derivation of the following words:

Occipital, from the Latin *occiput*, the back of the head.

Parietal, from *paries*, a wall.

Frontal, from *frons*, the forehead.

Temporal, from *tempora*, the temples.

Sphenoid, from the Greek *sphen*, meaning a wedge.

Ethmoid, from the Greek *ethmos*, meaning a sieve.

From a study of the above, what facts may you infer concerning the position, shape, or function of the different cranial bones?

55. The Face.—There are fourteen facial bones, and all but two are in pairs. They assist in forming the cavities which open on the front of the face—that is,

the mouth, the nose, and the eyes. The characteristic appearance of the faces of different individuals is largely due to variations in the shapes of these bones.

The two single or median bones are the lower jaw-bone, or *inferior maxillary*, and the *vomer*, which forms a large part of the partition between the nostrils. The remaining bones of the face are in six pairs as follows:

1. The *nasal*, two small bones at the middle and upper part of the face, forming by their junction the "bridge" of the nose;

2. The *lachrymal*, at the front part of the inner wall of the eye cavities—the smallest and most fragile of the facial bones;

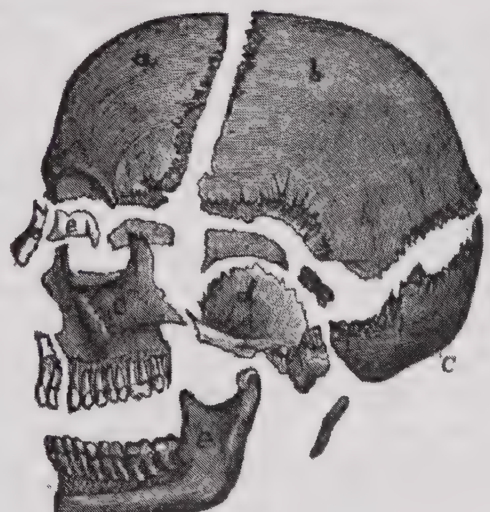


Fig. 31.—The Bones of the Skull Separated.
a, frontal; b, parietal; c, occipital; d, temporal; e, e, e, e, facial bones.

3. The *superior maxillary*, or upper jaw-bones;

4. The *palate-bones*, lying in contact with the inner surface and posterior border of the superior maxillary bones. They are shaped a little like the letter L, and are wedged in between the upper jaw-bone and a part of the sphenoid;

5. The *malar*, two small bones of irregular shape

which form the prominences of the cheeks and also a part of the outer wall of the eye cavities;

6. The *inferior turbinated*, thin, spongy bones, situated within the outer wall of the nose.

56. The Hyoid Bone.—Besides the cranial and the facial bones, there is a small U-shaped bone, called the hyoid, which lies in the neck on a level with the lower border of the inferior maxillary. It is just above the "Adam's apple," and is the bone to which the muscles of the tongue are attached.

57. Practical Questions.—What is the chief use of the cranial bones? of the facial bones? of the hyoid bone?

What is the general shape of the skull?

What are the cavities which open on the front part of the face?

What bones aid in forming the nose?

What bones aid in forming the cavity of the mouth?

How many bones are there in the head? Make a classified list of them.

How many are in the head and trunk taken together?

What parts of the axial skeleton give support to the other parts?

What parts give protection to delicate and important organs?

What additional ideas do you acquire by studying the following words and their derivations?

Maxillary, from *maxilla*, a jaw-bone.

Vomer, from *vomer*, a plowshare.

Nasal, from *nasus*, the nose.

Lachrymal, from *lachryma*, a tear.

Turbinated, from *turbs*, a whirl.

IX.—THE APPENDICULAR SKELETON.

58. What parts of the entire human skeleton are not included in the axial skeleton? These parts taken together are called the *appendicular* skeleton.

FIG. 32.—THE SHOULDER BLADE.

The appendicular skeleton consists of two parts: (1) the *shoulder girdle* and the upper limbs; (2) the *pelvic girdle* and the lower limbs. These parts are also designated as: (1) the upper extremities; (2) the lower extremities.

59. The Upper Extremities.—The shoulder girdle is the medium of connection between the skeleton of the trunk and that of the arms. It consists of two bones on each side, the *clavicle* and the *scapula*.

FIG. 33.—IDEAL REPRESENTATION OF THE SHOULDER GIRDLE AND ITS CONNECTIONS.

a, the spinal column; f, the ribs; g, the sternum; e, the clavicle; b the scapula; c, the shoulder joint; d, the humerus.

The clavicles, or collar-bones, form the front part of the shoulder girdle. Each clavicle is a long, slender

bone, and lies in an almost horizontal position just above the first rib. You have already learned (§ 50) that it is connected with the sternum; it articulates also with the scapula, and serves to give support to the upper extremity.

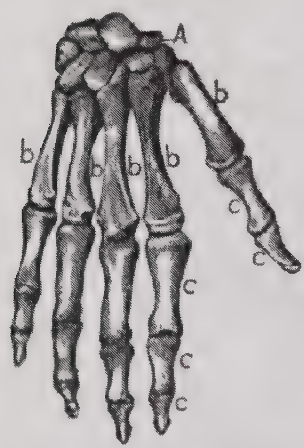


FIG. 34.—SKELETON OF THE HAND
A, carpal bones; b, metacarpal bones; c, phalanges.

The scapula, or shoulder-blade, is a large, flat bone, which forms the back part of the shoulder. It is triangular in shape, and is attached to the trunk solely by means of muscles (Fig. 32).

60. Each *arm* or *upper limb* has thirty bones. The largest is the *humerus*, or bone of the upper arm. The round head of the humerus is directed upward and backward, and articulates with a corresponding cavity in the scapula. This articulation is commonly called the shoulder joint.


FIG. 35.—BONES OF THE ARM.

In the lower arm, or forearm, there are two bones. The larger of these is the *ulna*, a long bone of prismatic form, which unites with the humerus at the elbow, forming a hinge joint. The smaller is the *radius*, which lies on the outer side of the ulna and is parallel with it. At its lower extremity it articulates with the first two bones of the wrist, forming the wrist joint.

61. The skeleton of the hand includes the *carpus*, or wrist bones, the *metacarpus*, or bones of the palm, and the *phalanges*, or bones of the fingers. The *carpus* is formed of eight small, irregular bones, bound closely together. Of the *metacarpal* bones, which are cylindrical in shape, there are five—one for each finger and one for the thumb. Of the *phalanges* there are fourteen—three for each finger and two for the thumb.

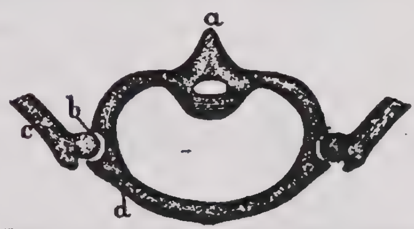


Fig. 36.—Ideal Representation of the Pelvic Girdle and its Connections.
a, the spinal column; d, the innominate bone; b, the hip-joint; c, the femur.

62. The Lower Extremities.—The pelvic girdle is the medium of connection between the axial skeleton and that of the lower limbs. It consists of two large bones, one on each side of the sacrum. These are called the *innominate* or nameless bones, perhaps because they bear no resemblance to any other named object. In childhood each of these bones consists of three pieces. At the point where these pieces come together and are finally ankylosed, there is a deep,

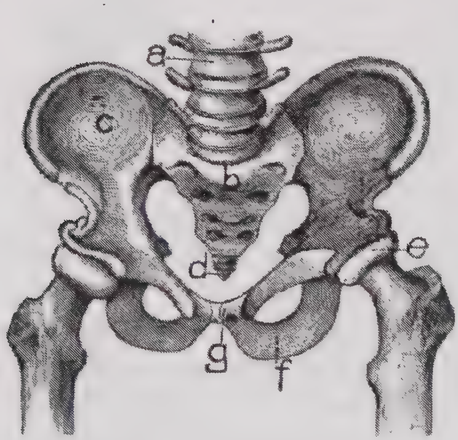


Fig. 37.—The Pelvis.
a, lumbar vertebræ; b, sacrum; d, coccyx; c, innominate bones; e, hip-joint; f, ischium; g, pubic arch.

cup-shaped cavity, into which the round head of the thigh-bone fits. The bones of the pelvic girdle together with the sacrum and coccyx form the walls of a basin-like cavity called the *pelvis*. These walls are stronger and more massive than the walls of either of the other great cavities of the skeleton (Fig. 37).

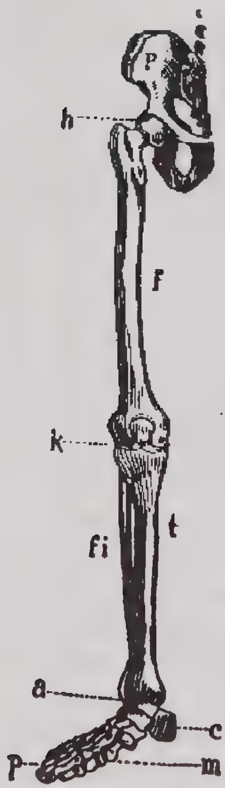


FIG. 38.—BONES OF THE LEG AND FOOT.

f, femur; k, patella; t, tibia; fi, fibula; a, ankle joint; c, tarsus; m, metatarsus; p, phalanges.

What are the three great cavities of the skeleton?

The pelvis acts as a support and partial protection to the organs contained in the abdomen, and as such, forms the lowermost portion of the trunk.

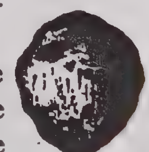


FIG. 39.—THE PATELLA.

63. The skeleton of the lower limb comprises the thigh, the leg, and the foot. The *thigh-bone* or *femur* is the longest and strongest bone of the body. The upper end or head of this bone is ball-shaped, and is fitted into the cup-shaped socket of the innominate bone in such manner as to allow great freedom of movement. This is called the hip-joint. (See Fig. 44.)

64. The skeleton of the leg consists of three bones: the knee cap or *patella*, the *tibia*, and the *fibula*. The patella is a flat, triangular bone on the front part of the knee, where it is loosely articulated with the femur. It serves not only as a protection to the knee, but aids

in the movement of the parts to which it is articulated.

The tibia is a large, strong bone at the front and on the inner side of the leg. It is connected above with the femur, forming the knee-joint, and below with the bones of the ankle at the ankle-joint.

The fibula, or splint bone, is a long, slender bone lying parallel with the tibia. Its upper end, or head, articulates with the tibia, while its lower end forms the outer prominence of the ankle.

FIG. 40.—SKELETON OF THE FOOT—LATERAL VIEW.
(The pupils should name the parts.)

65. The skeleton of the foot consists of the *tarsus*, the *metatarsus*, and the *phalanges*. The bones of the tarsus or ankle are seven in number. They are arranged in two rows, and are so shaped and bound together as to give to the sole of the foot a slightly arched form.

Of the metatarsus there are five cylindrical long bones, and at the end of each of these is the first bone of a toe.

The phalanges or bones of the toes agree in number with the phalanges of the fingers.

66. Review Questions.—What is the human skeleton?

Of what does the axial skeleton consist?

Of what does the appendicular skeleton consist?

How many bones are in the trunk? in the head?

How many bones are in the upper extremities? in the lower extremities? in the entire body? Make a complete classified list.

If the spinal column consisted of but a single bone, instead of thirty-three, what disadvantages would result?

If the vertebræ were not capable of being slightly moved, one upon another, how would our comfort be affected?

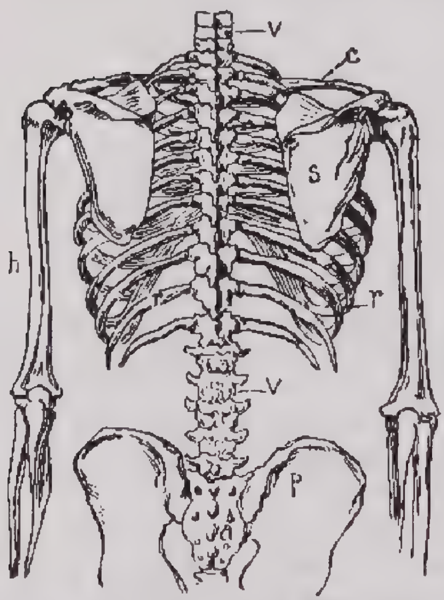


FIG 41.—Posterior View of the Skeleton of the Trunk and its Connections. (The pupils should name the parts.)

What advantages, if any, result from the double curves in the spinal column?

If the two uppermost vertebræ were exactly like those below them how would that affect the movement of the head?

Name three functions of the spinal column? Can you name more than three?

Describe the curvature of the ribs.

Are the ribs capable of any motion? Prove it.

If all were joined directly and firmly both to the backbone and to the sternum, what would be the result?

Are the costal cartilages of any use or advantage?

Name two functions of the ribs.

Which of the bones of the face, if any, are movable?

Which of the bones of the upper extremities acts as a brace to keep other parts in their proper position?

Explain how each of the two parts of the appendicular skeleton is connected with the axial skeleton.

How many bones are in each of the lower limbs? Make a classified list.

Compare the skeleton of the lower limbs with the skeleton of the upper limbs.

Compare the pelvic girdle with the shoulder girdle.

Why is great strength necessary to the femur?

What advantage, if any, does an arched instep possess over one that is not arched?

What effect will a habitual stooping position be likely to have upon the shape of the spinal column and the thorax?

What effect do ill-fitting shoes often have upon certain bones of the feet?

What effect will tight lacing be apt to have upon the ribs and costal cartilages?

Word Study.—What ideas respecting the shape, appearance, or uses of certain bones do you obtain from a study of the following words and their derivations?

Scapula, from Greek *skapula*, a spade.

Clavicle, from Latin *clavis*, a key.

Ulna, from Greek *olone*, the elbow.

Radius, from Latin *radius*, the spoke of a wheel.

Pelvis, the Latin word for basin.

Patella, the Latin word for small pan.

Tibia, the Latin word for flute.

Fibula, the Latin word for a clasp.

(Most of the other names, such as *humerus*, *femur*, etc., are merely the Latin words for the part of the skeleton mentioned, and have no other meanings.)

X.—THE JOINTS.

67. **A Joint.**—The union or junction of any two contiguous bones is called a joint or an articulation. It is by the joints that the various bones of the body are united to form a skeleton. The different parts or substances which compose a typical joint are *bone*, *cartilage*, *ligaments*, and *synovial membrane*.

68. Bone is, of course, a necessary part to every joint. The long bones, in most cases, form their articulations at their two ends; and we find these the most perfect of movable joints. The flat bones are joined to one another or to other bones, at their edges. The short bones form articulations on different parts of their surfaces; but usually at their ends, as do the long bones.

69. Cartilage is an important element in the formation of many joints. In these joints it incrusts with a smooth, thin layer the parts of the bones where the articulation is formed. The incrustation varies in thickness, being the most abundant where the pressure is the greatest. By its smooth surface it affords ease of movement and lessens friction. Being also highly elastic it acts as a soft cushion between the parts and breaks the force of sudden jars.

70. **Ligaments** are found in all those joints which admit of movement. They are strong, white bands, composed chiefly of fibrous tissue (§ 130) laid side by side and closely bound together. They are very tough

and flexible, and are firmly attached to the bones, thus holding them together.

71. Synovial Membrane is a delicate membrane attached by its edges to the incrusting cartilages in the joints. It secretes a viscid yellowish white fluid, somewhat like the white of an egg. This fluid is called the *synovia*. The function of the synovia is to lubricate the contiguous moving surfaces. It thus prevents friction between the parts, and makes all movements easier.

FIG. 42.—White Fibrous Tissue.

72. Kinds of Joints.—There are two classes of joints, the *immovable* and the *movable*. Some physiologists designate a third, the *mixed*, which includes such as are but slightly movable.

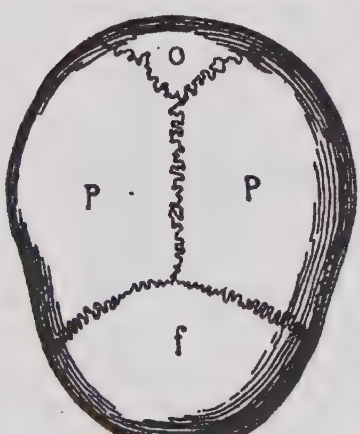


FIG. 43.—Top of the Skull, showing sutures. Let the pupils name the bones.

The bones of the cranium are connected together by means of *sutures* (Fig. 43). A suture is an immovable joint formed by the interlocking of the toothed margins of adjacent bones. The word *suture* is also applied to the notched edges themselves. A joint of this kind may be compared to the interlocking of two pieces of carpenter work by means of what is known as the dovetail.

73. Of movable joints in the skeleton there are a great number, as well as several different forms. The

simplest form of movable joint is that which permits the two bones to slide, or glide one upon another. This kind of articulation is called *arthrodia*, and examples of it are found in the backbone, the carpal joints, and the joint between the sternum and the clavicle. It admits of very little motion.

FIG. 44.—Vertical Section of Hip Joint.

74. In strong contrast to the arthrodia are the joints which permit motion in all directions. In this form of joint the globular head of a long bone is received into a cup-like cavity in the flat or irregular bone with which it is connected. Its common name, *ball-and-socket joint*, serves well to describe it (Fig. 44). The ball is kept in its place by strong ligaments and ligamentous bands.

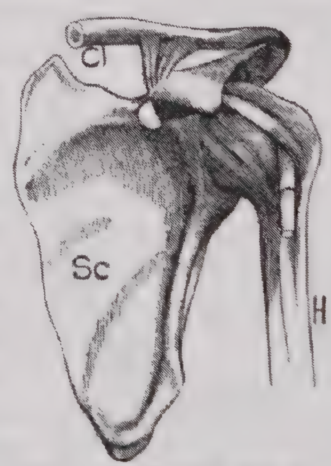


FIG. 45.—The Shoulder Joint (posterior view).

Name two familiar examples of ball-and-socket joints (§ 60, § 63).

75. The *hinge joint* is made up of two corresponding surfaces so fitted to each other as to admit of motion in only two directions, backward and forward, as in a hinge. Here also strong ligaments are necessary in order to hold the parts in place.

Name one of the most familiar hinge joints in the body (§ 60).

76. Another form of articulation is that which admits only of rotation, first in one direction, then in the other. Here the joint is formed by a kind of pivot, one bone turning within a ring in the other. This is sometimes called a *lateral hinge joint*.

Mention and describe one lateral hinge joint (§ 45).

Still another kind of joint is that found in the wrist. See what a variety of movements is here. The construction of this joint is of a complex character, and we need not describe it minutely. It is called a *condyloid* articulation.

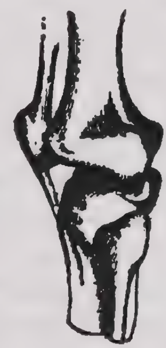


FIG. 46.—THE KNEE JOINT. Showing position of the patella and ligaments.

77. Mention has already been made (§ 43) of the articulations of the vertebræ forming the spinal column. Between each vertebra and the vertebra next to it there is an elastic pad of cartilage, called the *intervertebral disk*. This pad is closely united by its surfaces with the body of each of the vertebræ between which it lies. By its compression and expansion it permits a certain amount of movement on the part of the vertebræ. When the backbone is bent, or leaned to one side, each of these disks is compressed on that side and stretched a little on the other side. It is this peculiarity of the joints of the vertebræ which gives to the backbone its flexibility and thus adapts it to movement, however slight, in almost every direction.

78. The Joints and the Skeleton.—The joints may be

said to be parts of the skeleton in the same sense that the mortises, tenons, and other devices for holding together the framework of a building are said to be parts of that framework.

An artificial skeleton consists only of dry bones united together usually by wires. In such a skeleton there are many parts lacking, as the periosteum, the cartilages, the ligaments.

79. Questions for Thought.—In what particular ways does the construction of the bones and the joints promote ease and freedom of movement?

In what ways is strength provided for? In what ways are the effects of sudden jars or shocks provided against?

Which joint of the appendicular skeleton is so constructed as to admit of the greatest variety of movements?

Name a lateral hinge joint; a hinge joint; an immovable joint.

Seeing that the bones of the cranium are so closely united by sutures, why would not one continuous bone answer the same purpose just as well?

Of what use are immovable joints? How is a movable joint sometimes changed to an immovable one? (§ 34.)

In the bones that assist in locomotion, which class of joints predominates? In the bones whose function is protection which class predominates?

Of how many different kinds of movement does the wrist joint permit?

What is the most important lateral hinge joint.

How many joints are there in the backbone? In what class of joints would these be included?

How many different joints are there in the arm? How many of each class?

XI.—SOME PRACTICAL CONCLUSIONS.

80. Development of the Osseous Framework.—Physiologists have attempted to trace a relationship between the length of time required for the complete development of the osseous framework of the body and the average duration of life. In infancy a large proportion of the skeleton is composed of cartilage. The process of ossification (§ 31) is slow but continuous. The bones of the skull are not fully united until some years after birth. The spinous and transverse processes of the spinal column are not completely ossified until the twenty-fifth to the thirtieth year; other parts of the body remain in the cartilaginous state until advanced age. The period of growth, both of man and animals, continues until there is a complete union between the shafts and the ends of the bones. When this union takes place growth usually ceases. In man this occurs at about twenty years of age, in the dog at two, in the lion at four, in the horse at eight. Observations have shown that most species of vertebrates live about five times their period of growth; hence it is estimated that the natural life of man ought to be about one hundred years, of the dog ten, of the lion twenty, of the horse forty. But, in the case of man, a general disregard of the laws of health, the strain and wear attendant upon overwork, the effects of unhealthful surroundings, and various other causes have very materially lessened his natural span of life.

81. Why should we learn these facts about the bony framework of the body? In order that we may intelligently guard against its injury and provide for maintaining the health and strength of all its parts. It may readily be understood that if any portion of this framework is defective or diseased, or if it has been harmed in any way, other parts must also suffer, and the body as a whole cannot possess that perfect health, strength or symmetry that it otherwise might have.

82. **Injuries to the Bones.**—There are many ways in which the bones may be injured. They may be broken or fractured by accident. They may be dislocated at a joint. In such cases it is said the bone is "out of place," and all motion is impossible until the dislocated parts have been restored to their natural position. A severe wrench or sudden strain upon some part may produce what is called a sprained joint, the bones being so far moved out of place as to tear or otherwise injure the ligaments of the joints. These injuries are all more or less serious, and are sometimes difficult to heal. Ignorance or carelessness in their treatment may sometimes produce permanent deformity; hence such cases should always receive the attention of a competent physician.

83. **Improper Positions** in sitting, standing, or walking, if persisted in, frequently produce deformities of certain parts of the body. So, also, tight lacing about the waist will bend the ribs or the costal cartilages and finally change their form. Shoes that are ill-fitting or too small are likely to crowd the bones of the feet together and cause them to assume unnatural shapes. Fashion is frequently responsible for these and other deformities. (See § 525.)

84. **Improper or Insufficient Food** in childhood prevents or delays the perfect ossification and development of the bones. Sometimes this produces disease or causes distortion of some of the parts, as in the deformity called *rickets*.

85. **How Alcohol Injures the Bones.**—The bones of persons addicted to the use of alcoholic liquors are often weak and imperfectly developed. The alcohol, by interfering with the processes of nourishment, retards the growth of the young cells and prevents their proper development. The growth of the bones is hindered or perverted, and their strength is impaired. In some cases they become unduly enlarged, the marrow in the long bones being increased in quantity to an unhealthy degree. In persons who use alcoholic liquors, the nutrition of the tissues is so much impeded, that when a bone is broken or dislocated it is much more difficult to heal than in persons who use no strong drinks.

86. **Tobacco and the Bones.**—The use of tobacco by boys and young men has a like effect. The smoking of cigarettes, no less than the chewing of tobacco, is especially harmful. Tobacco in any form interferes with the nutrition of tissues and hinders the growth of the cells upon which the proper building up of the body depends. The bones, not being properly nourished, become stunted and in some cases misshapen, and the body never attains to that symmetrical development which it would otherwise reach in manhood. The young man or growing boy who wishes to possess a perfectly formed body, strong, graceful, and athletic, will be careful never to acquire the pernicious habit of using tobacco.

XII.—THE MUSCLES.

87. Muscles.—The bones, no matter how articulated or joined with one another, would be incapable of independent motion without the aid of other organs. This aid is afforded by the *muscles*.

The muscles are the flesh of the body. They have the peculiar power of contracting, or shortening; and it is by doing this that they move the bones upon each other at the joints.

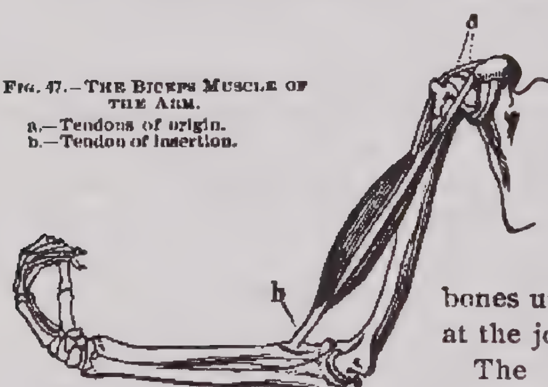


FIG. 47.—THE BICEPS MUSCLE OF THE ARM.
a.—Tendons of origin.
b.—Tendon of insertion.

The muscles are joined to the bones or other parts of the body either directly or by means of *tendons*. Even when connected directly, however, the muscles do not form a close union with either osseous tissue or cartilaginous tissue, but terminate upon the periosteum or perichondrium. Some of the muscles end in flat, ribbon-shaped tendons of pearly-white color called *aponeuroses* (Fig. 48).

88. Tendons are glistening white cords composed chiefly of fibrous tissue. They contain no nerves and but very few blood vessels. Unlike the muscles, they

have no power of contraction. They may be said to be the ropes which the muscles employ in the performance of their functions. They are of various forms and are always strong.

FIG. 48.—APONEUROSIS BELOW THE KNEE
a.—Muscle.
b.—Skin.
c.—Aponeurosis.

The tendons are in most cases merely extremities of the muscles modified and prolonged. The tendon which composes the fixed end of the muscle, and toward which it draws during its contraction, is called the *tendon of origin*. That which extends from the other end of the muscle to the part that is moved by the contraction is called the *tendon of insertion*.

89. Shapes of the Muscles.—The word muscle is derived from the Latin *musculus*, a little mouse, and is used in its present signification because of a fancied likeness between the shape of that little animal and of certain of the simplest forms of muscles. The typical muscle consists of a belly, or principal part, tapering to a single tendon at each end. A *biceps* or two-headed muscle, is one which divides at one end into two tendons. A *triceps* is one which divides into three tendons.

FIG. 49.—A TYPICAL MUSCLE.
a.—The belly.
b, b.—The tendons.

Some muscles have a tendon at only one end—the tendon of insertion—while in the other direction they

terminate abruptly at the point of attachment. A *digastric* muscle is one which consists of two typical muscles united by an intervening tendon (Fig. 51).

FIG. 50.—TENDONS OF THE HAND.

In one form the tendon extends the whole length of the muscle, the fibers composing the muscle being joined obliquely to the tendon. If they are joined upon one side only, it is called a *penniform* muscle; if upon both sides, a *bipenniform* muscle.

Many muscles are spread out into wide, flat masses, and have no distinct rounded portion, nor yet do they terminate in tendons. Circular muscles are those which have no direct attachment to any part of the skeleton, and whose fibers return upon themselves. Such are the *sphincters* which surround, and, by their contraction, tend to close a natural opening, as of the eyelids, the mouth, or the pyloric orifice of the stomach.

FIG. 51.—A DIGASTRIC MUSCLE.

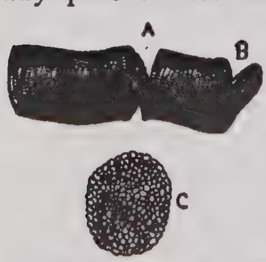


FIG. 52.—BUNDLE OF MUSCULAR TISSUE, TRANSVERSELY STRIPED.
C.—Cross section of the same.

90. Structure of the Muscles.—Muscular tissue constitutes the flesh, or "lean meat" of the body, and it enters into the composition of the walls of the internal organs or parts.

It forms therefore a large proportion of the gross material of the body.

The muscles consist in general of minute threads or fibers of muscular tissue, arranged in bundles and bound together. In some of the muscles these fibers are marked with transverse stripes, called *striæ;* in others there are no such stripes. The difference between these two kinds of fibers affords a basis for dividing muscular tissue into two general classes, the *striated* and the *nonstriated.*

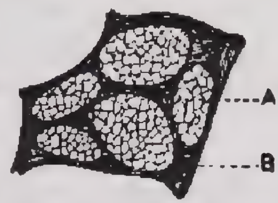


FIG. 53.—CROSS SECTION OF STRIATED MUSCLE.
A.—Fasciculi.
B.—Connective Tissue.

91. In the striated or striped muscles the fibers are invested by a sheath of delicate tissue called the *sarcolemma* and bound together by very fine connective tissue. These fibers are surrounded by a delicate network of blood vessels. The bundles in which they are arranged are called *fasciculi.* Many fasciculi lying parallel to one another and extending generally from the tendon of origin to the tendon of insertion, compose a muscle.

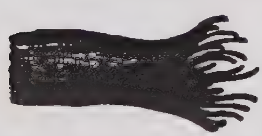


FIG. 54.—PORTION OF FASCICULUS OF STRIATED MUSCLE.

The size and texture of a muscle of this class depends, of course, upon the number and size of the fasciculi of which it is made up. The muscular fibers are generally of a cylindrical form and are from 1-2400 to 1-400 of an inch in diameter.

A familiar example of a muscle of the striped class is the large muscle of the arm.

92. In the nonstriped or nonstriated muscles, the tissue, instead of being composed of true fibers, is made

up of elongated cells called fiber-cells. These cells often cross each other and interlace; they are united together by a small quantity of adhesive matter. The fasciculi are separated one from another by a delicate connective tissue, and there is no sarcolemma. The cells are of a pale color—not red, as in the striped muscular fibers. They are of a rounded form, and are about 1-3500 of an inch in diameter and from 1-600 to 1-300 of an inch in length.

A good example of a muscle of the nonstriped class is the muscular coat of the stomach.

93. In both the striped and nonstriped muscles there are numerous blood vessels which penetrate the membraneous sheath and the connective tissue surrounding the fasciculi and the fibers.

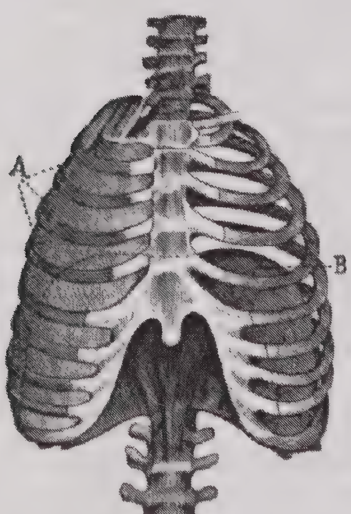


Fig. 55.
A.—Intercostal muscles.
B.—The diaphragm.

94. Number and Names of the Muscles.—There are in the human body about four hundred muscles. Each muscle is known to anatomists by a name which indicates its position, or its size, or its shape, or its attachments, or its mode of action, or a combination of two or more of the above. There are but few of these names that would be of interest to students of this book; and hence we shall mention only the following as examples:

The *orbicularis oris* is a sphincter muscle, elliptic in form, which surrounds the mouth.

The *masseter* and the *temporal* are powerful muscles which raise the lower jaw against the upper.

The muscular partition which separates the cavity of the thorax from that of the abdomen is called the *diaphragm*. This is the principal muscle of respiration. (Fig. 55.)

The muscles which are situated between the ribs, and aid in their movement, are called *intercostal* muscles.

The large, thick, triangular muscle which gives the rounded outline to the shoulder is called the *deltoid*.

The long muscle on the anterior surface of the arm is called the *biceps*, because at its upper end it is divided into two parts or heads. (Fig. 47.)

The *sartorius*, one of the muscles of the leg, is the longest muscle in the body.

There is on the outer and posterior part of the thigh another *biceps* muscle which is large and strong.

The broad, flat muscle which forms the calf of the leg is called the *soleus*. It terminates below in the great tendon, called the *tendo achilles*, which may be plainly felt just above the heel, behind the ankle. This tendon is the largest and strongest in the body.

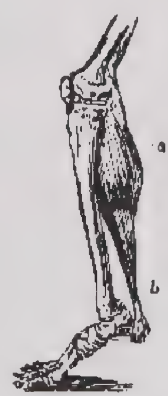


FIG. 56.
a.—The soleus.
b.—Tendo achilles.

95. A few general terms denoting the location or action of certain muscles are easily learned, and when known will aid the learner in understanding the meaning of other terms and explanations. It is well to remember that the muscles which move the arm or

the leg out from the body are called *abductors;* that those which draw it toward the body are called *adductors;* that the muscle by which any particular part is lowered is called a *depressor;* that there are also *compressor* muscles, which make narrower, and *dilator* muscles which widen or expand the parts to which they are connected.

96. **Functions of the Muscles.**—The essential characteristic of a muscle is its power of contractility—that is, its capability on the application of proper stimulus, of becoming shorter in length and dilating in breadth. It is by this change in form that the muscles become the means of imparting motion to different parts of the body.

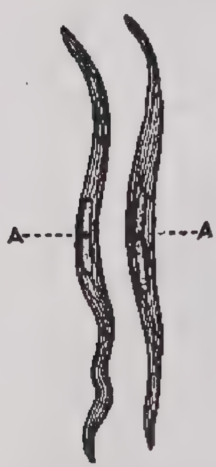


FIG. 57.—INVOLUNTARY MUSCULAR FIBERS.
A, A.—Nuclei of the fibers.

97. *Experiment:*—Grasp your left arm with the fingers of the right hand. Now bend the left forearm, and observe the change in the fleshy part of the arm which you are grasping. The muscle of that part loses its softness and becomes hard. This is the result of the forcible tension of the muscular fibers produced by their contraction. The muscle is apparently enlarged, and by the shortening of its length, the forearm is bent to the position which you desire.

What was the stimulus, in this instance, which caused the contraction of the muscle?

It was the impulse conveyed to the muscle by the motor nerve which is distributed to that part of the

arm (see § 409). But this impulse originated in your will.

98. Skeletal and Visceral Muscles.—In like manner other parts of the framework of the body may be made to change their position at the command of the will. The muscles which effect these voluntary changes of position are connected with various parts of the skeleton and for that reason are often called *skeletal* muscles. There are other muscles which are not attached to the bones of the skeleton, but are found within the interior of the body surrounding the cavities, tubes, and other organs that are concerned in the vital functions. These are called the *visceral muscles*, and they change their form independently of the will. They act without intention or thought on the part of the individual, and are not controlled by his wishes or commands. Yet they also require a nervous stimulus in order to perform their various functions. The muscles of the stomach and of the blood vessels are visceral muscles.

99. Voluntary and Involuntary Muscles.—You will understand from what has just been said, that all muscles are governed and regulated in their action by the nervous system. Nevertheless, as above noted, there are certain muscles, chiefly of the visceral class, which do not co-operate with the will, nor are they influenced by conscious effort.

Those muscles which are generally controlled by the will, or co-operate with it, are called *voluntary muscles.*

Those which perform their functions independently of the will are called *involuntary muscles.*

The voluntary muscles are of the striated, or striped variety. The involuntary muscles are generally of the nonstriated, or nonstriped variety.

100. Certain muscles in appearance, structure, or functions, seem to form a sort of intermediate link between the two varieties. The heart muscle is not attached to the skeleton, and like other visceral muscles it acts independently of the will; but in structure and appearance it strongly resembles the voluntary skeletal muscles. The muscles which control and regulate the act of breathing are attached to the skeleton and are of the striped, or voluntary variety; but they are only partially governed by the will. You may hinder their movements for a short time, but they will soon assert themselves in spite of your commands; moreover they perform their functions when you are asleep as well as when you are awake, and without any necessity of thought on your part. Under certain circumstances almost any of the so-called voluntary muscles may be made to act without the concurrence of the will, and sometimes even in direct opposition to its commands. The trembling of one's body when one is frightened or otherwise greatly excited, is a familiar example of the involuntary action of voluntary muscles.

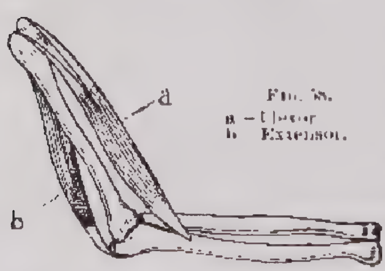


Fig. [illegible].
a — Flexor.
b. Extensor.

101. Contraction of the Muscles.—When a muscle contracts it becomes harder and more rigid; and the greater the force which it exerts, the greater does its rigidity become. When the contractile stimulus is entirely withdrawn, the muscle returns to its former state of repose, and the parts of the body that were moved by it may resume the position or form which they had before being acted

upon by it, or may remain at rest in some other position in which they have been placed.

102. Most of the muscles are in pairs—that is, if a muscle by its contraction moves a part of the body in one direction, there is generally a corresponding muscle which moves the same part in the opposite direction. Muscles which bend the parts to which they are attached are called *flexors;* those which restore the bended parts to their extended position are called *extensors*. The flexors and extensors are said to be antagonists, and yet, since both do not contract simultaneously, one does not interfere with the action of the other. If both muscles contract at the same time, no motion results, but only a state of complete rigidity very soon producing fatigue. (Fig. 58.)

103. Labor and Rest.—The relaxation of a muscle after contraction affords it an opportunity to rest and to recover the vigor which was expended in the effort of contraction. The feeling of fatigue which is experienced when any muscle is kept long in a state of contraction is a reminder of the absolute necessity of such rest. The involuntary muscles have their periods of rest which alternate with their periods of labor; for there is no exception to the rule that all parts of the body require rest. The muscular coat of the stomach is in action during the period of digestion, but at other times it is in a state of repose. The respiratory muscles which regulate and carry on the process of breathing contract several times in every minute; but between their periods of contraction they have as many periods of relaxation or rest.

104. Loss of Muscular Power.—In some diseases the power to control the action of the voluntary muscles

is partially or wholly lost. One of the most common manifestations of feebleness in old age is the inability to direct with precision the movements of certain parts of the body. The trembling hand, the unsteady step, the faltering voice, all are the results of a lack of power to control the contraction and relaxation of the skeletal muscles.

105. How Alcohol Causes Similar Disorders.—The use of alcoholic drinks, as beer, wine, ale, and other liquors, affects the muscles to a remarkable degree, producing various disorders both in those of the voluntary type and in those which act independently of the will. The tendency of alcohol is to destroy or derange the natural action of all living structures with which it comes in contact. It acts as a poison to all forms of life. When any alcoholic drink is taken into the system it mixes with the blood and is carried to the various tissues which compose the body. Alcohol is thus brought into contact with the delicate muscles which direct the voluntary movements of the hands, the arms, the head, the face, and other parts. As a consequence the nutrition and growth of these muscles are hindered, and they finally cease to respond readily to the commands of the will. Various disorders of motion ensue, such as tremor, spasms, convulsions, and palsies. The most common of these disorders is tremor, and is often witnessed in the trembling, twitching hands and the uncertain motions of a drinker of strong drinks. Even small quantities of alcohol may derange the action of the muscles and produce a temporary tremor; and if the drinking is continued the affection becomes permanent.

The use of alcoholic liquor very frequently produces

tremor of the hands and arms, making it difficult for the subject to do any work that requires accuracy of movement. The hands become weak and the fingers refuse to move as they are desired. Artists, musicians, and all other persons whose occupations require steadiness of nerve and exact control of the hand must shun the use of all alcoholic drinks if they would be successful in their business or avocation.

Alcoholic tremor, when it extends to the lower extremities, manifests itself in an awkward, irregular gait. The muscles which control the action of the legs and feet lose their power of concerted motion, and, not responding promptly to the will, a shuffling, staggering movement is the result.

In some cases the lips and tongue are affected, producing stammering or hesitation of speech. Persons who indulge in strong drinks often find it difficult to enunciate certain words or sounds with distinctness, and the speech of the confirmed drinker is always sure to betray him. There are instances also in which the use of alcoholic drinks has affected the muscles of the eyes, giving rise to a distressing disorder called *nystagmus*, a species of tremor which causes the eyeballs to move involuntarily and refuse to respond to the dictates of the will.

This loss of the power to control the voluntary muscles may, if the use of alcoholic drinks is continued, gradually become even more serious until palsy or alcoholic paralysis occurs. The latter affection is at first a mere feebleness which little by little extends to the hands, arms, and legs, resulting finally in partial or total loss of muscular power.

106. Tobacco and the Muscles.—The use of tobacco also tends to lessen muscular power, and, like alcohol, to make accuracy and steadiness of muscular action impossible. Those who desire to excel in occupations requiring delicacy of touch and movement, such as painting, music, and many of the mechanic arts, cannot afford to indulge in the use of tobacco, for it weakens their control of the voluntary muscles and makes it impossible for them to perform their work satisfactorily. The tobacco habit is almost always acquired in youth. The boy who abstains strictly from its use will have no desire to indulge in it when he becomes a man. Its injurious effects, especially upon young men, have become so generally recognized, that in several countries laws have been passed to restrict its use.

107. Practical Questions.—Extend your arm in a horizontal position and hold it still as long as you can comfortably do so. Why does it become fatigued?

The heart beats all the time, day and night. Why is not this an exception to the rule that rest must alternate with labor?

When a muscle contracts, it becomes shorter. Does it lose any of its weight? Is its actual size diminished?

Why does the contraction of a muscle produce rigidity, or hardness? Do the extensors, as a rule, perform as much or as heavy labor as the flexors?

In the act of walking, which muscles are brought most into action, the flexors or the extensors? Which in the act of lifting a weight? Which in the act of writing?

Is it reasonable to suppose that a person who uses alcoholic drinks can excel in feats of skill and strength?

XIII.—WORKING POWER OF THE MUSCLES.

108. The amount of work which a muscle is capable of doing depends upon several conditions. To be able to perform all its functions in a complete and satisfactory manner, it must be well nourished, it must be strengthened by exercise, it must be trained to skillfulness of action by systematic practice. On the other hand it must not be weakened by straining or overwork, and it must not be injured by the poisonous influences of alcoholic drinks, of tobacco, or of other narcotics.

A muscle's power of performance depends also upon its shape. As a general rule, the thicker the muscle, the greater the load it is able to move. A long muscle contracts more than a short one, and has therefore the advantage of moving a weight, or the part to which it is attached, through a greater distance. Hence in the body there is a great variety of long and short, slender and thick muscles, each one being adapted to the special work that it is intended to perform. Some are so constructed as to produce great range of movement with the exertion of little power; others are so made as to overcome great resistance while moving through only a limited space.

109. By exercise and training, the working power of many of the muscles may be wonderfully increased. Some of the methods of doing this will be fully discussed in another part of this volume.

110. **Muscular contraction** may be produced by the application of an artificial stimulus, as by passing a current of galvanic electricity through a nerve or a muscle. But even under this artificial excitation, the muscles are able to contract only for a limited time, and soon demand rest by relaxation.

111. **Straining.**—The habitual voluntary movements of the body, as in walking or changing the position of some part, are very different from the movements produced by real muscular effort. In the usual act of walking, the proper muscles contract and relax at the proper time without any distinct command from the will, and frequently without any conscious effort on our part. There is but little change in our breathing; there is but a slight quickening of the heart's pulsations. But, let us begin to run rapidly, or let us try to jump over an obstacle, to lift a heavy weight, or to make any other unusual physical effort—the muscles are at once brought into vigorous action. Other parts join with the muscles in the attempt to produce the desired results. This combined and semi-unconscious effort of various parts or organs is described in a homely way by the word *straining*. This straining cannot be continued very long; it cannot usually be prolonged beyond the time required for a very deep breath; if too great, or made too often, or continued too long, it is likely to result in serious, perhaps permanent injury to some of the organs.

112. **Injuries to the Muscles.**—There are many ways in which the muscles may be injured. Constant or prolonged labor without the alternation of the required periods of rest causes the cells composing the muscular tissue to be broken down more rapidly than they can

be formed (§ 14). A feeling of great fatigue ensues. The muscles are literally worn out; they become weak and small, and their power of contraction is partially or wholly lost. The use of insufficient or of innutritious food hinders the construction of new cells in the muscular tissue, and feebleness and disease result from the lack of nourishment. The habitual disuse of a muscle prevents its complete development. For instance, the left arm is generally weaker and smaller than the right, and the fingers of the left hand are incapable of performing many of the delicate movements which characterize those of the right.

The use of Alcoholic Drinks results in great and permanent injury to the muscles. It hinders their growth and development, causing them to become flaccid, weak, and pale. We have already seen how it interferes with their contracting power (§ 105), preventing the will from having complete control over those of the voluntary type. Alcohol frequently causes a change in the character of the muscular tissue itself. This change is called fatty degeneration, and consists in the deposition of particles of fat between the muscular fibers. In course of time so much may be deposited that many of the muscular fibers are crowded out and destroyed, and partially or wholly replaced by fatty tissue.

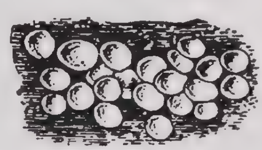


FIG. 59.—FAT GLOBULES.

In such cases there may be an appearance of health in the well-rounded arm or the rotund figure, but what to the eye seems to be strength-giving muscle and healthy muscular tissue is for the main part merely a mass of inert fat in which no strength resides. Thus,

men who drink beer and other alcoholic liquors frequently have large bodies and appear to be very strong, while in truth they have no strength; for instead of well-developed muscles they have only fat, which has no power of contraction or other movement.

Alcohol never increases muscular power, but on the contrary causes it to be diminished. Men who have hard labor to perform sometimes drink beer and other alcoholic liquors, thinking thus to increase their strength and endurance. But this is one of the delusions of alcohol. It may serve as a temporary stimulus, goading them to their labor, but it gives them no real addition of strength and in the end produces muscular exhaustion. Men are wise who avoid the use of all alcoholic drinks, for these drinks give neither nourishment nor strength, but interfere with the nutrition of the muscles and diminish their powers of endurance.

113. A Review of the Muscles.—Which classes of muscles are of the striped variety? Which are of the nonstriped?

What is a voluntary muscle; an involuntary muscle? What is a skeletal muscle?

In what part of the body are most of the voluntary muscles situated?

Name one muscle which is wholly involuntary. Can you name any muscle which is voluntary under all circumstances?

Are the muscles which lift the eyelids voluntary or involuntary?

Which muscle has the structure and appearance of a voluntary muscle and yet is not voluntary?

Which muscle forms a partition between two cavities of the body?

If a man had absolute control over his muscles of respiration what might be the result?

If the principal skeletal muscles were involuntary, what are some of the inconveniencies which might follow?

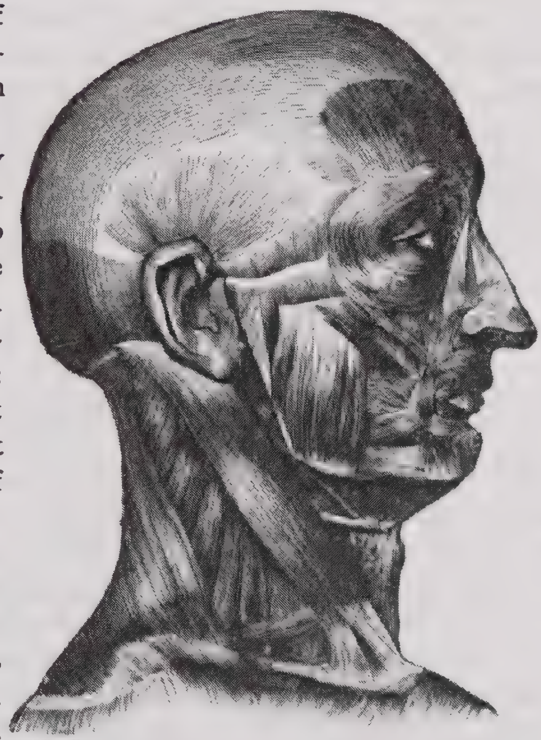


Fig. 60.—Muscles of the Head and Neck.

In ordinary walking we commonly take no thought of the muscles which cause the movement of the legs: shall we infer that these muscles act independently of the will? (§ 100).

How many movable bones are there in the face? Name two muscles of the face which are attached to a movable bone and aid in its movement? What is a sphincter muscle?

What purpose do many of the muscles of the face perform? To what general class of muscles do they belong?

Where is the tendon of origin of the biceps muscle of the arm? Where are the tendons of insertion of the same muscle?

Do the tendons themselves possess the power of con-

traction? Are they elastic? What is their general appearance? How do they differ from the ligaments which assist in forming the joints?

Give an example of a depressor muscle; of a compressor; of a dilator; of an extensor; of a flexor.

Why are the muscles of a blacksmith's arm large and strong? Why is a user of alcoholic drinks not likely to be a good marksman?

Why should a young man who wishes to excel in athletic feats abstain from the use of tobacco?

XIV.—MOTION AND LOCOMOTION.

114. Organs of Motion.—What are the organs of motion? The student who has read the preceding sections of this book will have no trouble in answering this question. Nearly all of the complex automatic movements of the body are produced by the co-operation of the bones, the joints, and the muscles. Most of the striped muscles are fixed by tendons of insertion to bones, and these bones are moved by their contraction. A few, however, which have no connection with bones, produce motion only in themselves or in the soft parts surrounding them, and have no effect upon the bones.

Generally speaking, it may be said that the muscles are the *active* organs of motion and the bones and joints are the *passive*.

115. The muscles and bones, besides being organs of motion, make it possible for the body to maintain

itself in a given posture. By *posture* is meant those positions of the body, in a state of equilibrium, which may be continued for a considerable time without fatigue. The three most common postures are standing, sitting, and lying. In any of these postures the bones remain at rest, and the muscles co-operate in maintaining the body in a condition of stability. Here too, then, the muscles are active, the bones are passive (§ 525).

FIG. 61.

Showing the action of the muscles in the standing posture.

116. Levers.—In studying the motions of the parts of the body we may regard the bones as levers. Let us learn something about the laws of motion in levers. A lever in mechanics is a bar or any rigid piece, acted upon at different points by two forces—the power and the weight—which tend to move it in opposite directions about a fixed point or fulcrum. A lever is said to be of the first, second, or third class, according to the relative positions of the two forces and the fulcrum. In a lever of the first class the fulcrum is between the weight and the point of application of the power. In a lever of the second class the weight is between the fulcrum and the point of application of the power. In a lever of the third class the point of application of the power is between the weight and the fulcrum.

117. In treating of the bones as levers we must regard the weight as being the entire amount of resistance to be overcome in moving the lever or bone. The

fulcrum is the joint where movement takes place. The power is the force exerted by the muscle. This power acts upon the lever at the point where the muscle is inserted upon or joined to the bone.

There are not many levers of the first class among the bones of the skeleton. Let us see if we can find one. Nod your head as you do in token of assent. In this movement the lever is the skull, the weight is the difference between the front part of the head and the back part; the power is derived from the muscles at the back of the neck, which by their tension keep the head in a state of equilibrium; and the fulcrum is the point at which the skull articulates with the spine. Now, when you desire to nod, the muscles at the back of the neck, which are ordinarily contracted, are relaxed and the head falls forward because of its own weight. There is no muscular effort, but rather a removal of effort. But immediately the muscle contracts and the head resumes its normal position—the power lifts the weight.

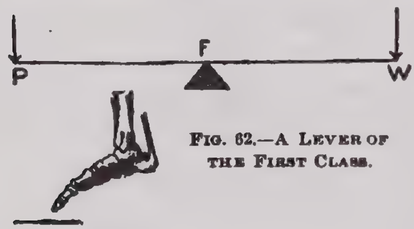


FIG. 62.—A LEVER OF THE FIRST CLASS.

FIG. 63.

What other levers of the first class are in the human skeleton? Explain the action of any one that you can think of.

118. Now study the action of the lever of the second class. A familiar example is a door when it is pulled with the hand on the latch. In this case the fulcrum is the hinges, the weight is the door's resistance, the

power is the force applied by your hand. In opening the door, which moves the farther, the weight or the power? Suppose that there is such a lever in the body. Think how much the muscle must contract in order to move even slightly the bone to which it is attached. The disadvantages of such a lever are such that no perfect example exists among the bones of the human body. Certain of the not very common movements admit of the principle of a lever of this class. For example, in standing on tiptoe the foot acts as such a lever. What is the power and where is its point of application? Where is the weight? Where is the fulcrum?

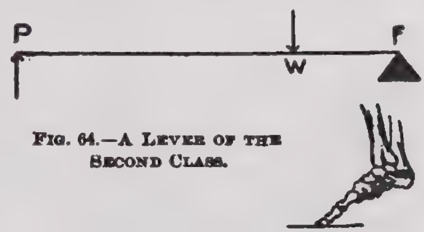


FIG. 64.—A LEVER OF THE SECOND CLASS.

119. Since there are in the body so few levers of the first or the second class, we must at once infer that most of the movements of the skeleton are performed by levers of the third class. Hold your right arm extended before you. Now bend the forearm toward you so as to bring the hand toward the shoulder. In this movement the forearm is the lever; the hand with a part of the forearm is the weight. What is the fulcrum? From what muscle is the power derived? Where is the point of application of this power?

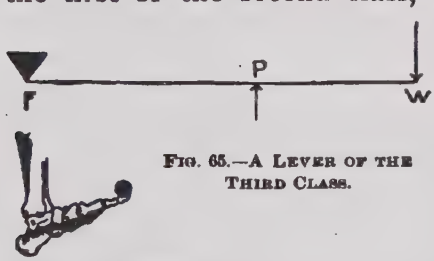


FIG. 65.—A LEVER OF THE THIRD CLASS.

In levers of the third class, which moves the farther and the faster, the weight or the power?

In overcoming the same amount of resistance, is more power required in a lever of this class, or in a lever of the second class?

What are the advantages of a lever of the third class? What are the disadvantages?

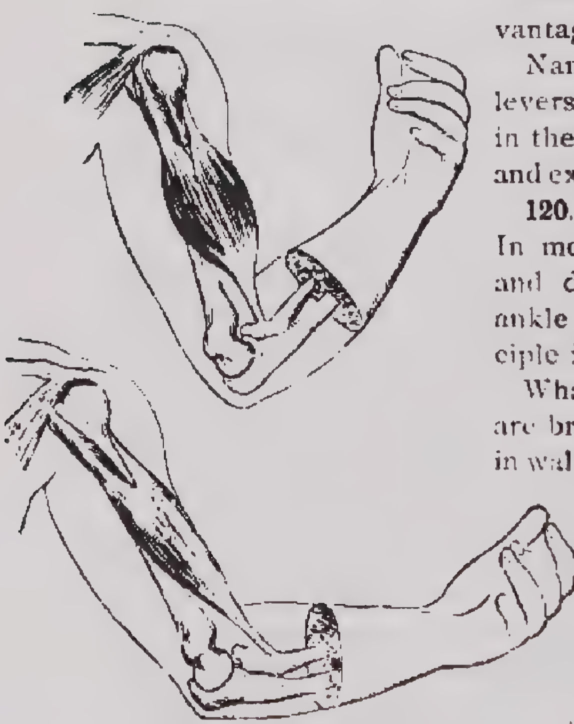


FIG 66.—BENDING THE ELBOW.

Name some other levers of the third class in the human skeleton, and explain their action.

120. Applications. — In moving the foot up and down upon the ankle joint, what principle is illustrated?

What kind of levers are brought into action in walking? In writing? In throwing a ball? Give a full explanation in each case.

In turning the head upon the shoulders, is any kind of lever put into action? If so, tell what is the fulcrum; the weight; the power.

Can you name any movement of a bone which does not involve one or another of the principles of a lever?

If the biceps muscle of the arm, which bends the elbow joint, were so attached to the forearm as to form a lever of the second class, what advantages and disadvantages would result?

121. It is well to observe that most of the muscles with their tendons act upon their attachments from an oblique direction—that is, in pulling upon a bone to lift it, the power is not applied at right angles but obliquely from one end. This is illustrated in Fig. 67.

You will observe that as soon as the weight has been lifted to a certain point, the power begins to act more nearly at right angles, and this disadvantage ceases to exist. Here is an example of the compensations in nature. For the force with which a muscle contracts is greatest at the commencement of its contraction—that is, just at the time when its position with reference to the weight puts it to the greatest disadvantage. As its force diminishes, the weight is brought into a position more favorable to its action.

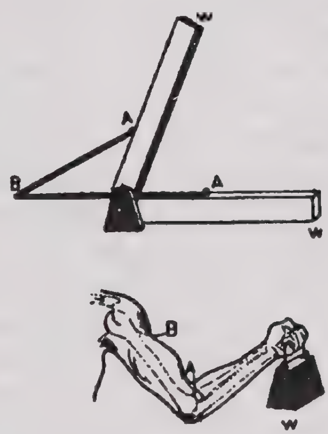


FIG. 67.
B.—The power
A.—The point of its application.
W.—The weight.

122. **Locomotion**.—By locomotion, in physiology, is meant the movement of the body from place to place by means of its own muscular exertions. It is effected, as the movements of individual parts of the body, by the muscles acting upon certain passive organs or parts, as the bones or the cartilages.

How many different kinds of locomotion can you mention?

What kinds of locomotion peculiar to certain animals are difficult or impossible to man?

123. *Walking* is performed with so little apparent effort that it seems to be a very simple operation. Nevertheless it involves a series of complicated movements, produced principally by the flexor and extensor muscles of the legs. The body does not at any moment leave the ground. Its weight is transferred alternately from one leg to the other, and is transmitted through the femur and the tibia to the bones of the foot and thence to the ground. In taking each step the body is inclined forward, thus throwing the center of gravity forward; to prevent the body from falling, the hinder leg is now brought to the front and the weight of the body is transferred to it. For a single brief moment, while this transference is being made, the weight of the body rests upon both legs at once. It may be said that walking is a process of continually recovering oneself from falling.

124. In *running* there is a moment after each step when both feet are entirely off the ground; and at no time does the weight of the body rest upon both legs at once. At each step the body is thrown forcibly forward, and the hinder foot leaves the ground before the other reaches it. The knee joint remains flexed as the foot comes down; but the moment the toes touch the ground the leg is straightened by a sudden exertion, and the body is again thrown forward only to alight upon the other leg in the same way. Running, then, may be said to be a succession of leaps, performed first by one leg and then by the other.

125. In *leaping*, both legs are flexed and then extended simultaneously, and the whole body is raised from the ground during an appreciable but brief length of time.

XV.—MORE ABOUT THE TISSUES.

126. **Classification of Tissues.**—What tissue constitutes the chief part of the human skeleton? What other tissue, somewhat similar to this in appearance and structure, is also a constituent part of the body's framework?

There is a third tissue the function of which is to hold the parts of the bony skeleton in their places. What is the general name applied to this tissue?

The first and second of the tissues above alluded to, perform certain functions which have already been considered. What are they?

Among these functions one of the most important is that of supporting or keeping in place other tissues and organs. Give one example of the manner in which the bones, or the cartilages, or both together support some particular part or parts.

127. **Protective Tissues.**—Another important function of certain bones and cartilages is that of protecting tissues. What do the bones of the skull protect? What do the vertebræ protect? What do the layers of cartilage on the ends of the long bones protect?

We shall learn as we proceed in our studies that there are several other tissues which have among their chief functions that of protection or support. All such are called *protective tissues.*

There is a peculiar tissue, which invests the bones and is instrumental in supplying them with the proper nourishment. What is the name of this tissue? What is the name of a similar tissue that invests the cartilages?

These also may be classified with protective tissues.

128. **Motor Tissues.**—What tissue has the peculiar power of contraction and therefore the power of giving motion to other parts? To it we may give the descriptive designation of *motor tissue.*

What name is given to the band or layer of tissue which is at the end or ends of a muscle and serves to attach it to some part of the skeleton? These tendons or cords are composed of a dense fibrous structure which, like that of the muscles, may be called motor tissue. It is also known as *tendinous tissue.*

Where are the ligaments situated? What is their appearance? They are composed of a strong, inelastic, fibrous material which we may call *ligamentous tissue.*

What is the special function of ligamentous tissue? It is a typical representative of that class of structures known as *connective tissues.*

129. The above classification, as will be observed, has reference chiefly to the functions of the tissues. There is another method of classification which is based upon the composition, form, or appearance of the tissues. For example, we speak of osseous tissue, muscular tissue, mucous tissue, thereby designating a certain structure having characteristics of formation which distinguish it from every other.

Many of the organs or parts of the body may be regarded as in the main composed of tissues peculiar to these parts alone. Thus, the bones are composed essentially of osseous tissue, the muscles of muscular tissue,

the fibrous membranes of fibrous tissue. But in the living bone there are other tissues besides the osseous. So also in most of the structures in the body, the tissue which is characteristic of the part does not exist there alone, but has other tissues mingled with it. For example, in a muscle, which is chiefly muscular tissue, we find blood vessels, nerve tissues, connective tissues, and other minor constituents. Hence, in speaking of a part or an organ, this blending of textures having different characters and functions should always be considered.

130. Fibrous Connective Tissue.—There are many varieties of connective tissue, differing from one another in appearance and structure, and in particular functions. One of the most important is that known as fibrous connective tissue.

FIG. 68.—AREOLAR CONNECTIVE TISSUE (Magnified).

Fibrous connective tissue exists in various forms. It is sometimes soft and delicate, with short fibers faintly marked. In this form it is a constituent part of the skin, and of the mucous membranes which line the interior cavities of the body.

It is sometimes loose and flocculent, with delicate filaments and perhaps small spaces called *areola*. In this latter form it is called *areolar tissue.*

It sometimes consists of strong and well marked fibers, lying either parallel to one another or crossing one another at right angles. This form is called *fibrous membrane.*

It sometimes appears in the form of rounded cords or flattened bands as in tendons and ligaments. It

is then called *tendinous* or *ligamental tissue.* The greater portion of most ligaments, tendons, and fibrous membranes is composed of *white fibers* of connective tissue, strong and inelastic. These fibers consist of very minute filaments or threads, united into bundles or fasciculi. The filaments lie almost parallel with one another and have a wavy course. Both the filaments and the fasciculi which they compose are firmly cemented together to form the hard tendon or ligament.

FIG. 69.—WHITE FIBROUS TISSUE.

There are also *yellow fibers* of connective tissue, and these form an important part of certain organs which we have not yet studied. They are found also mingled with the white fibers, in the skin, the fibrous membrane, and the ligaments. They too are arranged in bundles; but their filaments are much larger than those composing the white fibers. They are very elastic.

131. Adipose Tissue.—This tissue is the substance usually known as fat. It consists of round or roundish vesicles which vary in size from 1-800 to 1-300 of an inch in diameter. They are formed of very delicate membrane filled with fatty matter. This tissue is found as a layer beneath the skin; it exists in the cavity of the abdomen; it is a constituent part of the marrow of many bones; it is found in nearly all parts of the body.

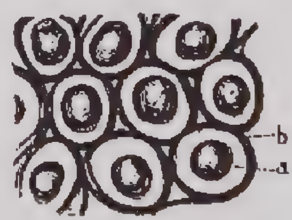


FIG. 70.—ADIPOSE TISSUE (Highly Magnified).
b.—Fat cells.
a.—Connective tissue.

132. Epithelial Tissue.—Every free surface of the

body, whether exterior or interior, is covered by one or more layers of cells. This covering, when it occurs on surfaces exposed either directly or indirectly to the air, is called epithelial tissue or *epithelium*. When it occurs on surfaces altogether inaccessible to the air it is called *endothelium*.

133. The free surface of the skin, which is the outer protective coat of the body, is therefore covered with epithelium. The protective coat of the internal passages and cavities which open directly or indirectly to the air, is called *mucous membrane*. Its free surface is also covered with epithelium. By observing the lips you may see how the mucous membrane merges into and is continuous with the skin.

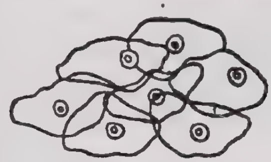


FIG. 71.—SIMPLE EPITHELIAL CELLS.

134. Epithelium, or epithelial tissue, consists of layers or strata of cells usually set compactly together. The cells of the deeper strata are generally smaller, softer, and more rounded than those on the surface. In the respiratory organs, the cavities of the brain, and some other parts, they are of a columnar form, packed close together and furnished with microscopic processes called *cilia*. Another variety is somewhat rod-like in shape and the parts are joined together by their sides into a membrane. This variety is called columnar epithelium. The outermost cells vary greatly in different localities. Those which compose the coating of the skin have a tendency to form a hard, impervious layer well adapted to the protection of the part which it covers. This layer is constantly being shed or cast off, the cells that are thus destroyed

being replaced by cells of the deeper layers which are modified in form and appearance as they are brought towards the surface. Epithelium contains no blood vessels, and with but few exceptions is devoid of nerves.

135. Membrane.—When any soft tissue or part exists in the form of a thin, pliable layer or sheet, usually investing or lining some other structure, it is called a *membrane.* Most membranes are composed partly or entirely of some form of connective tissue. They are known by various names. The *mucous membrane* is the layer or lining which covers the free surface of those internal parts that are exposed directly or indirectly to the air. *Serous membrane* is the smooth, tough lining of certain cavities of the body that are not exposed to the air. It invests or forms the outside covering of the stomach, the lungs, the heart, and other organs. Where is the synovial membrane, and what is its function? The periosteum and the perichondrium are also membranes.

FIG. 72. Showing General Structure of a Section of Mucous Membrane. (Highly Magnified.)

136. Review.—Make a list of the tissues, classifying them as to functions.

Make another list classifying them as to structure, or composition.

Make still another list classifying them as to appearance, form, or other characteristics.

What is a tissue? What is a fiber? What is a filament? What are fasciculi?

Describe the structure and appearance of a tendon.

In what respect is adipose tissue a protective tissue?

Is epithelium a protective tissue? Why do you think

so? With respect to its structure, to what class of tissues does it belong?

What is fibrous tissue? Name three structures that are largely composed of this tissue.

The bones, the cartilages, the muscles, combine to support and protect the various parts of the body. Name another structure that is indispensable to the protection of the body and the tissues composing it?

XVI.—THE SKIN AS A COVERING.

137. One Function of the Skin.—The bony skeleton would be a useless and unsightly thing were it not clothed with muscular tissue. The muscles, if left exposed and unprotected, would not only present a repulsive exterior but would soon lose their contractile power, be dried up by contact with the air, and become mere lifeless masses of flesh. As, therefore, the muscles are essential to the skeleton both for protection and for assistance in the performance of their natural functions, so also the skin is indispensable to the muscles in a variety of ways. Although it has numerous important functions, we shall at first consider it only in its capacity as a covering for the muscles or other delicate tissues in situations where they would otherwise be exposed to the air.

138. The skin thus considered is a protective tissue; at a later period in our studies we shall see how it has all the functions of an *excretive* tissue, while at the same time it may very properly be regarded as belonging to still a third class of tissues, the *respiratory*.

Considered simply in relation to its structure or composition, it is called *dermoid tissue;* but, as we shall soon see, it is made up of a variety of tissues, as epithelial, connective, elastic.

139. The skin consists of two layers. The inner one of these layers is called the *derma*, or true skin, and the outer one the *epidermis*, or *cuticle*.

140. The Epidermis.—What is epithelium? (§132.) Where does it occur? What are some of its peculiarities? If you cut it will it bleed? Does any injury to it alone produce pain? Give reasons for your last two answers. The epidermis is a true epithelial structure, composed of numerous layers of cells superimposed one upon another. It covers and protects the true skin. It is much thicker in some parts than in others. In the palms of the hands, and particularly in the soles of the feet, it is of a thick, horny texture, thus forming a more effective protection for the very sensitive derma. In the hands of persons accustomed to manual labor this layer is also here much thickened.

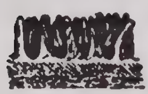


Fig. 73.—Papillæ.

141. The epidermis is so accurately moulded upon or united with the true skin, that it shows all the various ridges and depressions in the surface of the latter. These ridges and depressions are particularly noticeable in the palm of the hand and in the fingers. Open your hand and see how beautifully they are arranged.

What are these elevations and depressions?

The elevations mark the position and arrangement of certain conical structures called *papillæ*, in the true skin. The depressions are merely the spaces between

the papillæ—minute valleys between minute ranges of upland. We shall soon learn more about them.

142. Color of the Skin.—The epidermis has two layers or strata, a *superficial*, or *horny* layer, and a *deeper* layer. Each of these is made up of several layers of epithelium cells. In the cells of the deeper layer there is found a coloring matter, or pigment, which gives to races and individuals their peculiar and distinctive color. In the white races this coloring matter often appears in isolated spots called freckles or moles; in the darker races, as the negro, it is not only far more abundant but it is evenly distributed throughout the cells.

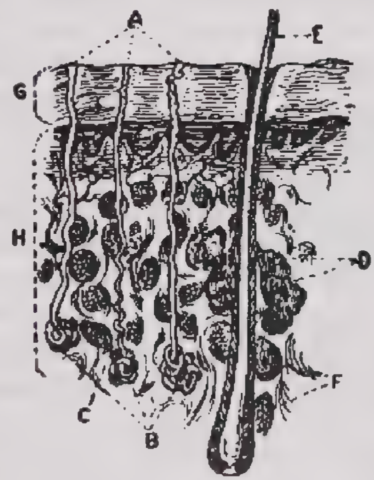


FIG. 74.—TRANSVERSE SECTION OF THE SKIN.

G.—Epidermis.
H.—True skin.
A.—Perspiratory ducts.
B. C.—Perspiratory glands.
D.—Sebaceous glands.
E.—Shaft of hair.
F.—Hair follicles.

143. The outermost, or horny layer of the epidermis is being constantly shed, or worn away; and hence the deeper layer is gradually approaching the surface, its cells changing and becoming a part of the horny layer. Thus the old skin is being constantly removed, and a new skin constantly supplied. The bran-like material that may sometimes be rubbed off the skin with a rough towel, consists of the dead epithelial scales of this horny layer. The dandruff which collects in the hair is the same thing.

144. As in all epithelial structures, there are no blood vessels in the epidermis. In the healthy skin the epidermis is closely adherent to the true skin, no distinct line of separation being noticeable. But in cases of scalds or burns, producing a blister, it is separated from it, and the space between the two layers is filled with a thin watery substance called *serum*. When the epidermis alone is injured it heals without leaving a scar; but if the injury extends through the true skin, a scar is sure to remain.

FIG. 75. — SECTION OF EPIDERMIS, VERY HIGHLY MAGNIFIED. Showing the Epithelial Cells.

145. The True Skin, or Derma.—A close observation of the true skin which lies beneath the epidermis reveals the fact that its surface is studded with small eminences arranged in rows or ridges. These eminences, of which we have already spoken, are called papillæ, and they are of much importance in connection with the sense of touch.

The true skin or derma (sometimes called the *corium*) consists mainly of connective tissue; it contains a considerable admixture of elastic tissue and is permeated with numerous blood vessels, nerves, and lymphatics. In the palms of the hands and the soles of the feet, the true skin is quite thick. One of its functions being to protect from injury the parts beneath it, it is everywhere tough, flexible, and elastic.

146. Appendages of the Skin.—Where the skin seems to end on the upper side of the last phalanx of each finger, what do you observe?

What is the shape of a perfectly formed finger-nail? How would you describe its texture and appearance?

A nail is simply a peculiar modification of the horny layer of the epidermis. The true skin lies beneath the nail, but it does not there contain as many papillæ as elsewhere. At the sides and the root, the nail is continuous with the outer layer of the skin.

New cells are being constantly formed at the root of the nail, and thus it gradually grows longer.

147. Each nail may be said to consist of three parts: the *root*, the *body* or exposed part, and the extremity or *free edge*. If the fingers were deprived of nails what would be the disadvantages? What, then, are the uses of the finger-nails? Of what use are the toe-nails? The nails of many animals are much more strongly developed than in man, forming claws which are in some cases long, sharp, and strong. Describe the claws of a cat; of a dog. What is the particular use of each?

FIG. 76.—SECTION OF THE TIP OF THE FINGER.

A.—Skin.
B.—Nail.
C.—Epidermis.
D.—True skin.
E.—Bone.
F.—Skin.

148. Hairs are also modifications of the epidermis and therefore appendages of the skin. They do not grow upon the palms of the hands, or the soles of the feet, or the surface of the upper eyelids; but upon all other parts of the skin they are more or less numerous.

Each hair consists of three parts: the *root*, the *shaft*, and the *point*. At its root, each hair has a bulbous enlargement which is imbedded in a depression in the skin called a *hair follicle*. The root of the hair is softer in texture than the shaft, and is composed of epithelial cells. The shaft of the hair also consists of epithelial cells. The cells composing the root contain granules of coloring matter, called pigment granules,

which also extend through the shaft. These pigment granules give to the hair its characteristic color. In white hair there are no pigment granules.

149. Glands of the Skin.—The glands of the skin are of two kinds, the *sebaceous* or *oil glands*, and the *sudoriferous* or *sweat glands*.

The sebaceous glands are small, sacculated organs situated in the true skin. They are found wherever there are hairs, and usually open by means of minute ducts into the hair follicles. They secrete an oily substance which softens the hair and the skin, and makes them pliable.

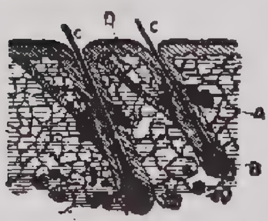


FIG. 77.—HAIRS.
(The pupils should name the parts.)

150. The sudoriferous, or sweat glands, are situated in small pits in the deep part of the true skin. Each consists of a coiled tube, from which a duct leads to the surface of the skin. A celebrated anatomist estimates the total number of the sweat glands in the body to be nearly two and a half millions. These glands act chiefly as excretory organs, removing from the body by their action many impurities and waste matters. But of this function of the skin we shall learn more when we consider the subject of excretions and excretory organs.

The skin acts also, to a certain extent, as an absorptive surface. Of this, too, we shall speak in a later chapter.

151. How the Skin may be Injured.—The skin being a protective tissue, it follows that much care should be exercised to preserve it from injury of every kind. Personal beauty is dependent to a large degree upon

the health and complexion of the skin. A sallow complexion, or a skin disfigured by blotches or eruptions, does not add to one's physical attractions. Such blemishes are often the result of a disordered state of some of the vital organs; they are sometimes the result of a lack of cleanliness; they are frequently produced by excesses of some sort or by ignorance of the laws which govern physiological conditions.

152. Many diseases of the skin are produced by the use of alcoholic drinks. A clear skin and a healthy complexion are seldom seen in persons who indulge in the drinking of beer, ale, wine, or other beverages of this kind. Alcohol frequently causes the skin to become dry, harsh, and scaly. The minute veins which carry blood through all parts of the true skin become enlarged. The skin of the face and especially of the nose and cheeks is particularly affected and assumes a purplish or violet hue, which plainly tells the story of indulgence in alcoholic drinks. The face of even the moderate drinker is often marked in this way.

Occasionally from the same cause the skin assumes a soft and oily appearance, and has a yellowish or earthy complexion; in other cases it acquires a dusky color, and becomes preternaturally smooth and glossy. Indulgence in alcoholic drinks can scarcely fail to leave its marks and to advertise itself in some way in the face of the person so indulging. To have a clear, healthy complexion, and to possess manly or womanly beauty, one must let such drinks absolutely alone.

The use of tobacco has also a deleterious effect upon the skin, and especially upon its complexion, frequently causing it to become of a tawny hue. Coffee sometimes produces a peculiar muddiness of com-

plexion. The excessive use of tea also affects the color of the skin.

153. Blemishes and Common Disorders of the Skin.—Warts are excrescences from the skin caused by the enlargement or excessive growth of the papillæ and of the epidermis. They sometimes occur also on parts of the mucous membrane. A corn is a thickening of the skin, generally on the toes, and is most often caused by the wearing of ill-fitting shoes. Pimples and eruptions of the skin, especially of the face, are frequently among young people the source of much annoyance, and sometimes produce permanent disfigurement. Attention to the general health by suitable diet and exercise and the shunning of all excesses, will often remove the cause of these blemishes, as also of many other disorders which affect the skin and the natural beauty of the complexion.

154. Practical Questions.—What useful purposes does the hair serve? Upon what is the color of the hair dependent?

When the pigmentary granules of the hair have disappeared, is it reasonable to suppose that they can be renewed by the application of so-called hair restoratives?

What purposes are served by the eyebrows and eyelashes?

Are hairs elastic? Determine by experiment the correct answer to this question.

What are two uses of the nails? Do the nails grow thicker at the same time that they grow longer?

Upon what does the color of the skin depend? What are freckles?

How is the true skin protected? Why does it need protection any more than the epidermis does?

XVII.—LIFE PROCESSES.

155. **The Body More than a House.**—We have now taken a view of the human body simply as a visible structure—as a shelter and home for the individual who speaks of it as "my body." We have compared it to a house, and we have considered its framework and its walls and its coverings. It has also chambers and passages for various uses. But here the analogy ceases. The body is much more than a house. It is an organism provided with apparatus for its own building-up, for the removal of such of its parts as grow old and useless, and for the renewal of these parts by the substitution of new materials derived from external sources. The *life processes* upon which these various operations depend are exceedingly complex and wonderful. They are carried on by the harmonious action of numerous parts or members, called *organs*, each of which is charged with the performance of certain definite functions.

156. Let us, therefore, proceed to a study of those organs and systems of organs by which the life of the body is maintained; and let us endeavor to understand to what extent our health and strength, and indeed our physical existence, are dependent upon the ability of each part perfectly to perform its particular function.

157. **Organs.**—The name *organ* is applied to parts as widely different in their structure as they are various in the character of their functions. The bones are

organs of support; the muscles are organs of motion; the skin is an organ of protection and also an excretory organ. There are digestive organs, circulatory organs, respiratory organs, vocal organs, organs of vision, organs of hearing, and many others. Some of the organs are in the form of solid bodies, as the bones, the teeth, the muscles; some are in the form of cavities of various shapes and sizes, as the mouth, the stomach; some are passage-ways opening from or into other parts or organs, as the veins, the lymphatics. Many have structures peculiarly their own, and admit of no general description.

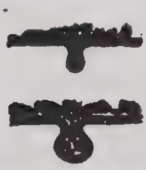


FIG. 78.—SIMPLE GLANDS.

158. Glands.—An important class of organs is that of the glands, peculiar structures which assist directly or indirectly in a very large number of the life processes. We have already learned certain facts about some of the glands of the skin. The original meaning of the word *gland* is "a little acorn," and this may aid you in forming some idea of the general shape of these organs, although they differ widely in appearance. But what is a gland? It is an organ, follicle, or other structure which produces some substance peculiar to itself, and, by so doing, assists either in carrying on the various complex processes through which the vital activities of the body are maintained, or in removing from the system substances which, if allowed to remain, would produce more or less injury to the bodily organs.

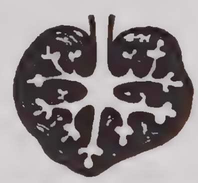


FIG. 79.—COMPOUND GLAND (Racemose).

There are, therefore, two general classes of glands, *secretory* and *excretory*. This brings us to a brief

consideration of the two important processes known respectively as *secretion* and *excretion*.

159. Secretion, in the sense generally understood, is the process by which some particular fluid—liquid or gas—is formed from materials supplied by the blood and is poured out upon some free surface, whether of an internal cavity or of the exterior of the body. The formation of *saliva*, the production of *perspiration*—these are familiar examples of secretion.

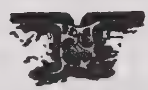


FIG. 80.—SIMPLE GLAND (Coil of Tubes).

If a fluid produced by secretion is intended to perform some special function in the body, it is called *a secretion*.

If a fluid produced by secretion has no further use in the body, but is formed merely to be removed, it is called an *excretion*.

Saliva is a secretion; the perspiration is an excretion.

Excretions are discharged from the body as useless matter. Secretions are generally, although not in all cases, taken up again in a more or less modified form into the blood.

FIG. 81.—COMPOUND GLAND (Tubular).

Some secretions, besides performing certain important functions, contain a greater or less amount of excrementitious matter which must in some way be removed from the system.

160. As we proceed with our studies we shall learn about many different kinds of glands and of the various secretions or excretions produced by them. We shall learn that the process of secretion is of the utmost importance—so important that life cannot exist without it. We shall also learn what are some of the special functions of different secretions, and how their pres-

ence or absence affects the operations of certain organs and the never-ceasing changes that are taking place in the living body.

161. Decay and Repair.—During every moment of life the body is undergoing many changes. Certain of the cells which compose the tissues, having performed the functions allotted to them, suffer decay; they are transformed into dead, useless matter, and are removed or excreted from the body. This process of change is necessary to life; its rate of activity may be modified by various means and by many circumstances, but it must go on and does continue without cessation.

FIG. 82.—STRUCTURE OF A PLAIN SECRETING SURFACE.
Showing Cells and Membrane.

The losses to the body through the removal of decayed and worn-out matter are equal in the aggregate to no small amount. Now this constant destruction and removal of the principles composing various parts of the body, makes necessary the constant appropriation of new matter from outside. To restore all losses, and to maintain the normal vigor and strength of the body, the system must be supplied with certain definite kinds of matter, containing the same chemical elements as compose the changing tissues. These elements are all found in the blood; they are carried by the blood to the parts where they are needed; and there they serve to form new tissues, the process of renewal going on at almost the same rate as the process of destruction.

162. It is from the blood, then, that the materials are derived which repair the decaying tissues. But how is the blood itself supplied with these materials? Chiefly from the food.

XVIII.—FOODS.

163. Classification of Foods.—Foods are derived from many different sources; indeed, all nature is tributary to man in this respect. From the animal kingdom are derived meats of all kinds, eggs, milk, and many other products. From the vegetable kingdom come fruits, edible roots, grain, and an endless variety of plant products. From the inorganic world are derived either directly or indirectly the various mineral substances necessary to the maintenance of health and strength. Into what three classes, therefore, may foods be divided with respect to their origin?

With respect to their nature and purpose they may be classified as follows:

1. Organic tissue-making foods;
2. Organic heat-producing foods;
3. Inorganic foods.

164. Organic Tissue-Making Foods.—These substances, which are also called proteids, embrace all animal and vegetable foods with the exception of fats, sugars, and starches. They are all rich in musculine, fibrin, gluten, casein, or albumen, and some of them contain two or more of these principles.

165. Musculine is the principle which constitutes much of the bulk of lean meat—muscular tissue. Of the many kinds of meat, lean beef is the most nutritious. Other meats,—the flesh of birds, fishes, and wild animals, pork, mutton, etc.,—have great nour-

ishing power, but the system will rebel against them if they are taken as a constant article of diet.

Meats are rendered much more digestible by cooking. The process of cooking serves to disintegrate the inter-muscular tissue, thus making the meat tender and easily acted upon by the digestive fluids. It also develops certain savors, which, besides being pleasant to the taste, no doubt stimulate the secretion of the digestive fluids. Muscular tissue, if used as an exclusive article of diet, is capable of sustaining life for an indefinite period.

166. Fibrin is found in the blood and in animal foods. It is not such an important nutritive principle as musculine.

167. Casein is found only in milk. It constitutes much of the bulk of cheese, and in this form is a valuable article of food. Milk, besides casein, contains butter, sugar, and inorganic salts. As an article of diet, milk is capable in itself of supplying adequate nourishment to the body. It contains all the elements which are essential to nutrition, and on this account is without doubt the most valuable single article of diet which we possess. The constituents of pure milk are, on the average, as follows:

	Per cent.
Water	87.50
Butter-fat	3.50
Casein and albumen	3.75
Milk sugar	4.50
Ash (mineral salts)	.75

This average composition has served as the basis in both state and city governments for the enactment of laws or ordinances, the purpose of which is to prevent watering, skimming, and other forms of adulteration.

168. **Albumen** is the nutritive principle which is found chiefly in the white of eggs. Although very important to the nutrition of the body, this element is not capable in itself of supporting life. Eggs, besides containing much albumen, contain fatty matter and organic principles in the yolk, and also much inorganic matter. Eggs are, therefore, a very nourishing diet.

Albumen and casein are both found in many vegetables which are used as articles of diet. They are then called *vegetable albumen* and *vegetable casein*, and as nutritive principles they are probably as valuable as though of animal origin. Vegetable albumen is found in the juice of vegetables, such as cabbages and turnips. Vegetable casein, *legumin*, is found principally in peas and beans.

169. **Gluten** is a highly nutritive principle found in the cereals—wheat, oats, rye, and barley. It occurs most abundantly in the grain of the wheat. Gluten exists in greater or less proportion in all wheat flour, and is the substance which permits bread to be of a porous character. Gluten is capable of sustaining life if used as a sole diet. Bread has been aptly called the "staff of life." It is an article of diet which is adapted to all the needs of the body, containing starch, gluten, and inorganic salts. Oats and corn also contain gluten, and are important articles of diet. With some people, oatmeal or corn meal is the chief food. Both are highly nutritious. Corn differs from most other grains in that it contains much oil.

Organic tissue-making food is absolutely essential to the nutrition of the body. Without it, living tissues cannot exist. If the body were denied this class of foods, although there should be a plentiful supply of

others, it would gradually waste away, and after a time death would result with all the symptoms of starvation.

170. Organic Heat-Producing Foods.—This class of foods does not contain nitrogen. The important principles belonging to it are sugars, starches, and fats. These are valuable and necessary foods, their chief function being the production and maintenance of bodily heat. The sugars and starches are known as *hydro-carbons*, and they are principally of vegetable origin. They form the bulk of man's ordinary food of this class.

171. Sugars are of various kinds—cane, grape, maple, and milk sugar, honey and molasses. Cane sugar is derived from the sugar cane; grape sugar comprises all sugars which exist in the fruits—apples, pears, grapes, peaches, etc. Maple sugar is obtained from the sap of the sugar maple, and is a variety of cane sugar. Honey and milk sugar are both derived from the animal kingdom.

So far as regards their chemical composition and characteristics, all vegetable sugars are included in the two great classes, cane sugar and grape sugar. Grape sugar is also known as glucose. It is in this form that all sugar is taken into the blood. Cane sugar and the starches are converted, by digestion, into grape sugar before being absorbed into the circulation.

Sugar as Food.—Dr. V. Harley, of the Royal Society of Great Britain, has recently published the results of some experiments bearing on the influence of sugar as food in the production of muscular energy. Some of his conclusions are as follows:

"1. Sugar when taken alone is a muscle food. Five

hundred grammes (seventeen and a half ounces) of sugar increased the amount of muscular work done on a fasting day from 61 to 76 per cent.

"2. The muscle-energy-producing effect of sugar is so great that 200 grammes (seven ounces) added to a small meal increased the total amount of work done from 6 to 30 per cent.

"3. When sugar was added to a large meal it increased the total amount of work that can be done from 8 to 16 per cent.

"4. The work done during a period of eight hours can be increased from 22 to 36 per cent. by taking 250 grammes (eight and three-quarter ounces) of sugar.

"5. When sugar is taken at 3:50 p. m., it not only obliterates the diurnal fall in the muscular power, which usually occurs at 5:30 p. m., but even causes an actual increase in the total amount of work done."

172. **The Starches** are found abundantly in the vegetable kingdom. They exist in the cereals—wheat, corn, rye, barley, etc.,—in potatoes, rice, sago, tapioca, arrowroot, and in various other vegetable foods. Starch is used abundantly as an article of diet. It is not absorbed into the system directly as starch, but by certain digestive processes it is changed within the body to glucose or grape sugar before being absorbed. Starch, though an important article of food, is incapable by itself of supporting life.

173. **The Fats and Oils** are derived from both the vegetable and the animal kingdom. The principal kinds of fat used ordinarily for food are the animal fats—butter, lard, suet, and various fats of meat. Cotton-seed oil and olive oil are derived from the vegetable kingdom, and are valuable articles of diet.

Of the fats, butter is no doubt the most important food. Fats, though of great use in the proper nutrition of the body, cannot by themselves support life. Their chief value as foods lies in the fact that they are more powerful heat producers than sugars and starches; but they are not so easily digested.

174. Inorganic Foods.—Inorganic food consists of mineral salts and water. These exist in greater or less proportion in all the tissues of the body, and must, therefore, be supplied to them through the food.

175. The most important mineral salts, and their relation to the tissues of the body, may be easily learned by reference to the following table:

Name.	*Where Found.*
Chloride of sodium (common salt).	Found in every tissue of the body excepting the enamel of the teeth.
Phosphates of lime, magnesia, soda, and potassium.	Found in every tissue of the body.
Carbonate of lime.	Found principally in the bones, teeth, and cartilages.
Sulphates of sodium and of potassium.	Found in all the tissues. Not in the bile or gastric juice.

176. The most important of all the inorganic foods is without doubt water. It is found in every part of the body, and enters into the composition of every tissue. All articles of diet contain water; vegetable foods contain it in large proportions. It is an absolute essential to all forms of life.

Water serves as a solvent, aiding in the removal of

all waste matter and in the carrying of nutrition to the tissues. (See § 484.)

In what ways is water supplied to the system? Name some solid foods which contain a good deal of water (§483). Is it possible to support life long without drinking water? How? When does one feel the need of water most?*

177. The Need of a Variety of Food.—Besides a general demand upon the part of the system for food, there exists a demand for a variety of food. Each of the tissues requires for its nutrition certain special elements. Thus the bones require one class of elements, the muscles another, nerve tissues another. Some kinds of food contain certain elements, other kinds contain other elements; hence the use of a variety of foods is necessary to supply the needs of all the tissues. If you should eat but one kind of food for a considerable length of time, nature would rebel and the food would soon become very distasteful and the demand for other kinds of aliment would be pronounced.

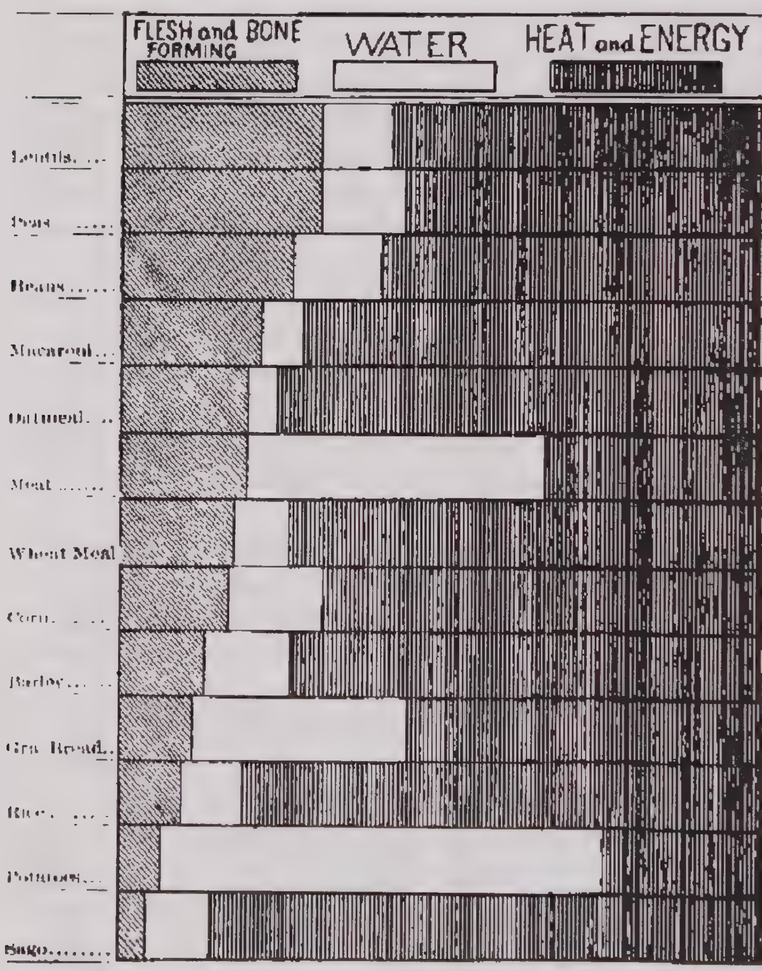
178. The Effects of Improper Food.—By improper food we mean aliment which is not thoroughly adapted to all the needs of the body. Such food, while it may preserve life and sufficiently nourish some of the

*The amount of water in each 1,000 parts in the body is shown in this table:

Enamel of teeth	2	Ligaments	768
Teeth	100	Blood	780
Bone	130	Bile	905
Cartilages	550	Saliva	983
Skin	575	Perspiration	986
Muscles	725	Tears	990

tissues, does not nourish others. As a consequence, while certain parts of the body are strong, others remain weak, and the general health is impaired.

RELATIVE VALUE OF STAPLE FOODS.



XIX.—SUBSTANCES NOT FOODS.

179. Narcotics. — There are certain substances which, although in no sense foods, are taken by some people into their systems, thereby producing various evil consequences. Chief among these are alcohol and tobacco, some of the effects of which have already been noticed. They belong to a certain class of drugs known as *narcotics*, and, far from being beneficial to those who indulge in their use, are productive only of harm. All narcotics have a stupefying influence upon the brain and nerves, and are highly deleterious to the health and strength of the body.

180. What Is Alcohol?—Alcohol is a colorless liquid which looks much like water, but which is very burning to the taste, and has a peculiar, penetrating odor. In its separate state it is a purely artificial product, having no existence in nature. Undiluted with other substances, it is an active poison. Living beings, whether animals or plants, if immersed in it, die almost immediately. Small quantities, if taken into the stomach, are productive of harm, and sometimes of very serious consequences.

181. Alcoholic Drinks.—In its undiluted form alcohol is of so deadly a nature that it cannot be used as a beverage. It is available for such purpose only when it is combined with other substances, or diluted with milder liquids, having a pleasant taste. The most common alcoholic drinks are cider, beer, ale, wine, brandy, and whisky. In some of these there is

a much smaller amount of alcohol than in others, but its poisonous qualities remain in all, and its effects are harmful in proportion to the quantity imbibed. All alcoholic liquors, as indeed alcohol itself, are the result of a process called fermentation. They are produced from substances which before fermentation occurred were wholesome and nutritious foods. By fermentation, therefore, that which was once fitted to sustain life becomes changed into a substance inimical to health and productive of disease.

182. What Is Fermentation?—Fermentation is essentially a destructive process. We are familiar with many of its forms, such as the putrefying of meat, the decaying of fruits, the rotting of grain, the souring of milk, the moulding of bread. It is constantly going on around us; for it is nature's method of disintegrating organized substances which have ceased to live, and of setting free their parts in order that they may not cumber the earth, but may enter into other forms of life. The cause of fermentation was for a long time a mystery. It was popularly supposed to be merely a spontaneous chemical process in which old compounds were broken up and new ones formed. Some writers contented themselves by merely saying that it was "nothing but the decay of a sweet liquid." Very recent investigations have shown conclusively that this mysterious process of decay is due to the presence of minute living objects known by the general name of *bacteria*. These micro-organisms may be found in the air, where they float unseen, and ready at the first favorable opportunity to begin their work. They are of many different kinds; each kind has its own particular class of substances upon which it lives,

producing its own particular form of fermentation. Some act upon meats, and give rise to what is called *putrefactive fermentation*. Some prey upon the sugar in fruits and grain infusions, changing it into carbonic acid and alcohol through the process known as *vinous fermentation*. Others are the producers of *acetous fermentation*, changing the alcohol of any fermented liquor into vinegar. Those which are concerned in vinous fermentation and the production of alcoholic liquors are popularly known as *ferments*, and to this class belong other similar forms of life, as the well-known yeast plant. How does the yeast plant produce fermentation in bread-making? (§479).

183. Alcohol from Fruits.—The micro-organisms known as ferments are, as we have said, common in the air, especially at the time when fruit is ripening. They alight upon any substance which seems to be favorable for their growth and propagation. When fruits begin to ripen the ferments collect upon their stems and skins. The delicate bloom which covers the surface of ripe grapes, or which is sometimes seen on an apple or a pear, is largely composed of these and kindred minute living organisms—germs of tiny plants waiting for an opportunity to grow and multiply. So long as the fruits remain entire, the ferments can do them no harm, for they cannot penetrate the unbroken skin. But when the juice is pressed from apples or grapes, some of these tiny objects, being washed into it from the skins or stems, seize upon the sugar in these juices in order to secure from it the oxygen which is their necessary food. But as they consume this sugar, they leave in its place other substances of quite a different nature. What are they? One is a gas which

bubbles up to the top and escapes; this is carbonic acid gas. Another is a liquid, and its name is alcohol. The alcohol, mingling with the other constituents of the apple-juice, produces *cider;* or, mingling with what remains of the grape-juice, it is called *wine.* This is the simplest way of producing alcoholic beverages. The production of all other alcoholic drinks is the result of a like process—the action of ferments upon the sugar contained in the fruits or grain infusion. In every one hundred pints of hard cider there are from five to fourteen pints of alcohol. In wine there is a much larger proportion of alcohol, amounting sometimes to one-fifth or even one-fourth of the whole. If old cider is allowed to stand, another class of ferments attack it and change its alcohol into acetic acid. It is now called vinegar, and is entirely free from alcohol.

Many persons have become confirmed drunkards by beginning with the drinking of cider; for, although this liquor contains but a small proportion of alcohol, the amount is sufficient to create an appetite for strong drink, which, unless resisted, is sure to lead to indulgence in other beverages.

184. Alcohol from Grains.—Of all alcoholic drinks, beer is the most largely used. Many people partake of it daily under the mistaken idea that it is a food and affords them nutriment and strength. It belongs to the class of beverages known as malt liquors, and is usually made from barley. Other liquors are made from rye, wheat, or corn. These grains in their natural state contain a large quantity of starch and but little sugar. It is much more trouble, therefore, to make beer than to produce wine or cider; for, in

order that vinous fermentation may take place in the grain, the starch must first be converted into sugar. This is done by a process called brewing. The barley is at first thrown into a vat or cistern, where it is covered with water and allowed to soak until the grains become soft and begin to swell. It is then allowed to dry in a warm room. The seed germs begin to sprout, just as would have happened if they had been planted in the ground. They grow rapidly, and the starch which was stored up in the grains and which could not be dissolved in water, is changed into sugar which is soluble in water. This is the sugar which the brewer wishes to use in the making of alcohol. It is the natural food of the growing plant, and if nothing were done to prevent, it would soon be consumed. But the sprouting grain is now thrown into a hot chamber, where the sprouts are shriveled and die. The plants are killed, but the sugar remains unharmed. The grain is now called malt. The brewer next grinds and crushes the malt, pours on warm water, and mashes it in a vat, thus dissolving the sugar. The sweet liquid mass is now called wort. It is boiled with hops, then it is drawn off into large tanks, where it is cooled and yeast is added to produce fermentation. And now the process is the same as with the fruit juices. The yeast ferment breaks up the particles of sugar, and changes them into alcohol and carbonic acid. The alcohol remains in the liquid, while the gas comes to the top in bubbles, covering the surface with a yellow scum.

The brewer allows the mixture to stand until it has acquired the desired strength, when he draws it off into strong casks or barrels, which are closed air-tight

and kept in a cool place. In one hundred glasses of beer there are usually four or five glasses of alcohol. Ale, porter, and stout differ from beer only in containing a larger proportion of alcohol.

185. Baking and Brewing.—The baker uses grain and yeast and makes bread, which supplies nutriment and vigor to the body. The brewer also uses grain and yeast, but he makes beer, which gives neither nourishment nor strength. Why is it that from the same substances one produces a food and the other an article which is in no sense a food? The two processes of bread-making and beer-making are entirely different. In the former, the object is to preserve all the nourishing elements in the grain, and to make it palatable and wholesome. In the latter, the object is to change the starch into sugar, which is in turn acted upon by the ferment and turned into alcohol and carbonic acid, thus destroying the nourishing element in the grain. In the bread the strength-giving constituents of the grain are all preserved; in the beer they have nearly all been destroyed. In well-baked bread neither the alcohol nor the carbonic acid remains; in the beer the alcohol forms a most important ingredient, without which no one would care to drink it. The fermentation of the bread continues but a few minutes, and is stopped by the heat; that of the beer goes on even until it is used as a drink. The baker saves all his grain, and produces a wholesome food; the brewer destroys his grain, and produces an unwholesome liquor.

186. Mistaken Ideas about Beer.—Many people use beer under the mistaken idea that it is a nourishing food. Many drink it because they think it will "tone up the system." But the facts in the case are exactly

the opposite. Beer does not act as a healthful tonic to the system; it does not give strength. The use of it can lead to no good result; it may be the cause of infinite harm. Many men who drink beer have large bodies and appear to be very strong; but in truth they are not strong, and the largeness of their bodies is due to the unnatural accumulation of fat, the result of indulgence in beer-drinking.

187. Alcohol is a great deceiver. It blunts a man's sensibilities, and instead of relieving fatigue, prevents the tired man from realizing his exhausted condition. It also makes one believe that he is stronger after having taken a drink, when in truth he soon grows weaker and less able to perform any laborious task.

188. We have spoken particularly of beer because it is the most common of all alcoholic drinks. Cider and wine are also familiar examples of fermented liquors. But there are other alcoholic drinks which are much stronger and consequently more injurious. These are the distilled liquors, whisky, rum, gin, and brandy. They are made by subjecting fermented liquors to a process called distillation, and usually contain from forty to sixty per cent. of alcohol.

189. People who indulge in the habit of drinking beer, cider, wine, or any other of the weaker fermented liquors, are quite likely soon to acquire an appetite for alcoholic drinks. This appetite constantly demands more and more alcohol, and finally will not be satisfied with the weaker liquors, but must have something strong. In this way the taste for distilled liquors is acquired, and indulgence in beer leads to indulgence in whisky and brandy.

A number of eminent physicians have joined in the

following statement regarding this accumulative action of alcohol: "Alcohol, like all other substances of a narcotic nature, has the power when taken frequently, even in small quantities, to create a diseased appetite for more, which may become uncontrollable, and its gratification destructive." Are you willing to become a slave to this appetite? Are you willing to lose your power of self-control and allow this deceiver to be your master? Your only safe course is never to taste any alcoholic liquor.

Many hundreds of years ago a very wise man said: "Wine is a mocker, strong drink is raging; and whosoever is deceived thereby is not wise." This is as true now as it was in those ancient days when the physiological effects of alcohol were but little understood.

190. **How Drunkards Are Made.**—No person desires to be a drunkard. The haggard look, the inflamed eyes, the purple face, the bloated body which mark the habitual tippler are offensive and disagreeable to everybody. This condition is the result of continued indulgence in drinks containing that insidious poison, alcohol. The man who now excites your contempt and pity was not always thus. He began by taking the first drink. It was probably a drink of beer or cider, and was thought to be entirely harmless. But from this first drink and those that followed it, the appetite for alcohol began to be excited, and there was a desire for more. Each successive indulgence only increased the desire for more, and before he was aware, the drinker was a slave to his appetite and unable to resist its cravings. Stronger and stronger drinks were demanded, the power of self-control was completely lost, health and strength gave way, and the man became the pitiable wreck that you now see.

XX.—THE DIGESTIVE SYSTEM.

191. Digestion.—The food, in order to be of service to the body, must itself undergo numerous changes. Its nutritious portions must be separated from the non-nutritious; and the former must be put in a fit condition to be absorbed, or taken up, by the blood and carried by it to the tissues to which it is to serve as nutriment.

The process by which the food is thus made available for the needs of the system is called *digestion.*

The assemblage of organs by which this process is carried on is called the *digestive system*, or the *digestive apparatus.*

192. Organs of Digestion.—There are several different organs of digestion and each performs its own peculiar functions.

Some of these organs receive the food, and by processes that are chiefly mechanical, prepare it for the important changes which it must undergo. Others assist in converting the digestible portions of the aliment into a semi-liquid *chyle*, which is of such composition and consistency that it is capable of being absorbed and used for the nourishment of the body. Still others aid in separating the undigested from the digested parts and in preparing the former for excretion and the latter for absorption.

193. The Alimentary Canal.—In the lowest forms of animals the digestive system is exceedingly simple, consisting solely of a sort of pouch or sack with only one opening. Food introduced into this pouch be-

comes digested and is absorbed by contact with its walls. The animal itself is little more than stomach. It may be turned inside out, the former outside surface becoming the interior, and still the process of digestion will be carried on.

As a general rule the digestive system of every animal includes an opening for the entrance of food, a definite digestive cavity or chamber called the *stomach*, and a tube of greater or less length leading from this cavity. This entire passage-way for the food during the processes of digestion is called the *alimentary canal.*

194. As animals advance in the scale of existence other parts are added to the alimentary canal, thus increasing its structural complexity and adding to its general efficiency. In the carnivora, or flesh-eating animals, whose food contains but a small amount of indigestible matter, the alimentary canal is comparatively short, being when stretched out only three or four times the length of the body. In the herbivora or plant-eating animals the canal is much longer. In man, whose food is derived from both animal and vegetable sources, it is five or six times longer than the body.

In all the more highly organized animals, and therefore in man, the alimentary canal consists of a number of divisions or compartments into which various secretions necessary to the digestive processes are poured. This canal, together with the organs and parts that are connected with it for the performance of the digestive functions, constitutes the *digestive system.*

195. Divisions of the Alimentary Canal.—The alimentary canal, being several times longer than the body, is for the most part coiled up within the abdom-

inal cavity. It consists of a number of divisions or compartments which open into one another from above downward. These compartments are the *mouth;* the *pharynx*, or throat; the *esophagus*, or gullet; the *stomach;* the *small intestine*, a long and slender tube; and a larger but shorter passage-way, called the *large intestine.*

196. The alimentary canal is lined throughout with a delicate tissue called the *alimentary mucous membrane.* Next to this membrane and forming the middle layer of the walls of the alimentary canal there is a layer of submucous membrane; and on the outside of this is another layer of tissue composed mostly of involuntary muscular tissue, which helps to strengthen the walls, and by its contractions causes the food to move along the canal from above downward.

197. In the walls of the alimentary canal there are numerous blood vessels and other vessels called lymphatics; and opening on its inner surface are the mouths of a great many ducts from the various glands connected with the digestive system. Some of these glands are of considerable size and lie outside of the alimentary canal; others are very minute and are imbedded in the walls of the canal itself. The fluids secreted by these glands and poured out through the ducts into the interior of the canal, are mingled with the food, and by acting upon it, render it soluble and make it capable of being absorbed.

XXI.—THE MOUTH.

198. The Mouth Cavity, or **Oral Cavity**, is the dilated beginning or first division of the alimentary canal. It is bounded on the front and sides by the lips, the gums, and the cheeks; above by the palate; below by the floor of the mouth and the tongue, and behind by the pharynx.

The mucous membrane which lines the mouth terminates on the lips, where it merges into the skin of the face. It is a part of the general lining of the alimentary canal and is continued from the back of the mouth into the pharynx. This membrane is of a rose-pink color during life and is covered with scaly epithelium. (Fig. 83.)

FIG. 83.—EPITHELIUM FROM THE MUCOUS MEMBRANE OF THE MOUTH.

199. That part of the roof of the mouth which forms the partition between the mouth and the nose is called the *hard palate*. The mucous membrane covering it is more dense and tough than that of some other parts. Continuous with the hard palate and projecting downward and backward from the roof of the mouth is another structure called the *soft palate*. It forms a membraneous fold or curtain between the oral cavity and the pharynx.

At the middle of the edge of the soft palate is a conical process, called the *uvula*, which hangs downward. On each side of the back part of the mouth, at the entrance into the pharynx, is a glandular organ or process called the *tonsil*. These organs are oval in

form and are much larger in some persons than in others.

Apply the tip of the tongue to the front part of the roof of the mouth and move it backward; the distinction between the hard palate and the soft palate may be readily perceived.

Stand before a mirror and open your mouth very wide, depressing the tongue. You can see the various parts of the mouth cavity — the cheeks, the gums, the palates, the uvula, the tonsils.

FIG. 84.—Showing how the Milk Teeth are displaced by the Permanent Teeth.

200. The Teeth. — The front borders of the upper and the lower jaw-bones form two semicircular processes called the *alveolar processes*. These processes contain sockets or cavities for the reception of the *teeth*, and are covered by the gums. In old age, after the loss of the permanent teeth, these processes are absorbed and the entire bone becomes much thinner.

Two sets of teeth are developed. The first appear in early childhood and are called the *temporary*, or milk teeth; they are shed within a few years and are replaced by a second set, called the *permanent teeth*.

The number of teeth is by no means uniform in different individuals, but generally there are twenty in

the temporary set, and thirty-two in the permanent set.

201. Every tooth consists of three distinct parts: the *crown*, or that part which projects above the gum and can therefore be seen in the mouth; the *root*, which is that part imbedded within the jaw-bone; and the *neck*, or narrowed portion between the other two parts.

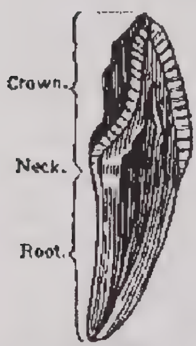


FIG. 85. — VERTICAL SECTION OF A TOOTH.

The cavities in the alveolar processes are lined with periosteum and this is reflected back upon the root of the tooth, covering it as far as its neck.

202. Of the thirty-two permanent teeth, there are in each jaw four *incisors*, two *canines*, four *bicuspids*, and six *molars*.

The incisors are the cutting teeth. Their crowns terminate in sharp horizontal edges and are wedge-like in shape. Each incisor has a single long, conical root.

The canines are directly behind the incisors, one on each side of the jaw. Their crowns are large and thick and taper to a blunt point. The roots, which are single, are long and thick and sink deeply into the jaw.

FIG. 86.—INCISORS.

In flesh-eating animals the canines are usually long and strong, and are adapted for seizing their prey and tearing it in pieces.

The bicuspids are directly behind the canines, two on each side of the jaw. They are smaller and a little shorter than the canines. The root of a bicuspid is

usually single, with a deep groove on each side partially dividing it into two parts. The separation is sometimes complete, especially in the root of the upper second bicuspid.

The molars are the largest of the teeth and are adapted for grinding the food. They are directly behind the bicuspids, three on each side of the jaw. The roots of the molars are divided into several parts, or fangs, varying in number from two to five. The hindmost molar is termed the *wisdom tooth*, and does not usually appear until several years later than the other permanent teeth. The number and arrangement of the teeth may be better understood by observing the following diagrams:

FIG. 87.—CANINE.

TEMPORARY OR MILK TEETH.

mol.	ca.	in.	in.	ca.	mol.
2	1	2	2	1	2

PERMANENT TEETH.

mol.	bic.	ca.	in.	in.	ca.	bic.	mol.
3	2	1	2	2	1	2	3

FIG. 88.—TEETH OF A FLESH-EATING ANIMAL.

The temporary, or milk teeth, are smaller than those of the permanent set, and their position in the jaws is less oblique.

203. Structure of the Teeth.—If a tooth be sawn through vertically it will be seen to consist of several distinct structures. In the interior there is a space called

the *pulp cavity*, which opens through a small hole at the tip of the root. In the living tooth this cavity contains a soft, sensitive substance called the *dental pulp*. The pulp is well supplied with nerves and blood vessels, which enter the tooth through the hole at the tip of the root. Any injury or exposure of the nerves in the dental pulp is likely to cause pain or continued aching. (See Fig. 92.)

FIG. 89.—MOLARS.

The solid part of the tooth is composed of three structures: *dentine*, *enamel*, and *cement*.

The dentine forms the greater part of the tooth. In the crown of the tooth it is covered with enamel; in the root it is invested in cement. It is a modification of osseous tissue, and is composed of earthy and animal matter.

FIG. 90.—BICUSPIDS.

The brilliant white layer which invests the crown of the tooth, is called the enamel. It is not only the hardest part of the tooth, but it is the hardest tissue in the body. Ninety-six per cent of its substance is earthy matter, consisting chiefly of phosphate of lime. The free surface of the enamel of an unworn tooth is covered with a very thin, horny membrane called the *cuticle of the enamel*. This membrane is worn off the crown by use. In persons who eat much hard food the enamel on the grinding surface of the molars is often worn down flat, and sometimes even down to the dentine.

The cement, or the *crusta petrosa*, covers the root of

the tooth and continues as far as the beginning of the enamel. Its structure is very similar to that of bone, and for that reason it is sometimes called *tooth bone.* It grows thicker as the bone grows older, and sometimes closes up the hole leading to the pulp cavity. When this occurs the nutrition of the tooth is prevented, and it soon becomes loose in its socket and drops out. Sometimes the dental pulp is slowly converted into a hard substance, and a similar destruction of the tooth ensues.

FIG. 91.—MOLAR OF A HERBIVOROUS ANIMAL.

204. The Tongue.—The tongue, although it has other important functions, acts in concert with the teeth in the *mastication* or *chewing* of the food, helping to move it about in the mouth, testing its fitness to be swallowed, and finally forcing it back into the pharynx, where it enters the esophagus.

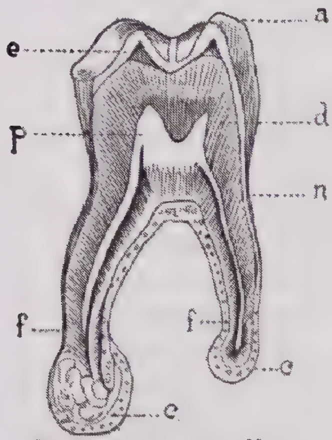


FIG. 92.—SECTION OF A MOLAR
e, enamel; a, cuticle of enamel; d, dentine; n, the neck; f, root, or fang; c, cement; p, pulp cavity.

The tongue is a mobile, muscular organ covered with a mucous membrane upon which there are numerous minute eminences called *papillæ.* These give the tongue its characteristic roughness. On the sides of certain of these papillæ, and embedded in the epithelial tissue, are numerous small flask-shaped bodies richly supplied with nerves. These bodies are of importance in con-

nection with the sense of taste and are called *taste goblets.* The tongue is attached at its base to the hyoid bone (§ 56) by means of several muscles. The tip of the tongue and part of its sides and under surface are free. Frequently, when the digestive organs are disordered, the tongue is covered with a yellowish white coating. This coating is composed of worn-out epithelium, a little mucus, and numerous minute organisms called *bacteria.* It is caused by the sympathy which exists between all parts of the mucous membrane of the alimentary canal—a sympathy which causes a disorder in one part soon to manifest itself in another.

FIG. 93.—THE TONGUE—NATURAL SIZE.

The tongue assists both in the mastication and the swallowing of the food.

205. The Salivary Glands. — The division and grinding of the food by the teeth is called the act of *mastication.* While this act is going on another important digestive process is also taking place in the mouth cavity. This is the incorporation of *saliva* with the food—a process commonly called *insalivation.*

What is saliva? It is a fluid composed of secretions from certain glands called *salivary glands.*

It is the fluid which moistens the mucous membrane of the mouth, and which is mixed with the food during mastication in order to make it more easily capable of being swallowed. It has the chemical property of transforming starch into sugar, and its admixture with the food is necessary to the proper digestion of the latter in subsequent stages of the digestive process.

FIG. 94.—THE MOUTH CAVITY AND THE SALIVARY GLANDS.
A, Parotid glands. B, Submaxillary glands. C, Sublingual glands. D, D, D, Salivary ducts. T, Tongue. L, Lips.

There are three pairs of salivary glands; the *parotid*, the *submaxillary*, and the *sublingual.* The *parotid glands* are the largest, and lie, one on each side, in front of the ear and behind the lower jaw. The saliva from this gland flows through a duct about two inches long and about the size of a goose quill. This duct crosses the cheek and opens into the mouth opposite the second upper molar tooth.

The *submaxillary glands* are near the angles of the lower jaw-bone and immediately below it. Their ducts open on the floor of the mouth.

The *sublingual glands* are the smallest of the salivary glands. They lie beneath the mucous membrane of the

floor of the mouth. They have from ten to twenty ducts, most of which open directly on the floor of the mouth.

206. The Saliva.—When the pure saliva which is secreted by the salivary glands is poured through the salivary ducts into the mouth it becomes mixed with a certain amount of *mucus*, a fluid secreted by small mucous glands in the mucous membrane of the mouth. The mixed saliva is a cloudy liquid, slightly alkaline in its reaction.

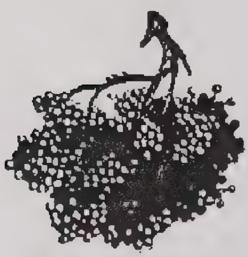


FIG. 95.—STRUCTURE OF THE PAROTID GLAND.

Saliva is being formed and poured into the mouth at all times, but much more rapidly during the acts of mastication. The mere sight of agreeable food excites the glands to increased action and causes the mouth "to water." Extreme nervousness or fright has the opposite effect and causes temporary suppression of the salivary secretion. In India a peculiar form of trial known as the "rice ordeal" was formerly practiced which was based upon this physiological fact. The accused person was given a handful of parched rice to eat. If he was guilty, his fear of detection would probably cause a suppression of the salivary fluid, the rice would remain unmoistened in his mouth, and he would be unable to swallow it; on the other hand if he was innocent, his clear conscience would generally prevent uneasiness, and no such result would follow.

The kind of food has also an influence upon the secretion and flow of saliva. If the food is dry or hard, or otherwise difficult to masticate, the saliva is secreted more rapidly than when it is soft, moist, and easily

chewed. A noted French physiologist, M. Lanceraux, has found that the use of alcoholic drinks produces a softening of the salivary glands, together with other changes in the tissue composing them. This, of course, causes alterations in the saliva itself, and accounts for the dryness of the mouth so common among persons addicted to the use of alcohol.

The average total amount of saliva secreted in a day by a healthy adult has been estimated to be nearly three pounds, about half of which is secreted in the intervals between meals.

207. The chewing of tobacco or of chewing gum causes an increased flow of saliva and induces a habit of spitting.

Give reasons why this habit is injurious to the salivary glands.

Why are persons who drink beer, ale, whisky, or other alcoholic beverages so often afflicted with a dryness of the throat?

Give one reason why they are troubled with morbid thirst.

One of the most dangerous effects of alcohol is the creation of a thirst or appetite for more and more liquor of the same sort. The person who once acquires the alcoholic habit finds it difficult to resist the temptation to continue drinking more and more. Each glass produces a desire for another, and finally the person becomes a slave to this unnatural appetite. It is in this way that the alcohol habit is acquired and men become drunkards.

208. Practical Review.—What is the first action to which the food is subjected in the process of digestion?

Why is mastication necessary?

What kinds of food require but little mastication?

What is the chief material in the composition of the teeth? Which wears away the more easily, dentine or enamel? Why?

What is the cause of toothache?

What change should we need to make in our food if our teeth were all incisors? What change if all were molars?

What animal has molar teeth only?

Which of the teeth do you suppose are the hardest to extract? Why?

Give two reasons why every person should take good care of his teeth.

What are the organs of mastication?

Why may the tongue be called an organ of digestion?

If water is taken into the mouth to moisten the food does it have the same effect as saliva? Why?

What is the number of salivary glands?

Might not the mucous glands in the walls of the mouth also be called salivary glands?

What is the cause of the mouth watering?

What are the advantages of chewing the food well?

Why does great fright or anxiety sometimes cause one's mouth to become dry?

209. Word Study.—What do you learn from a study of the following derivations?

Parotid, from Greek *para*, near, and *otos*, the ear;

Molar, from Latin *mola*, a mill;

Bicuspid, from Latin *bis*, two, and *cuspis*, a point;

Canine, from Latin *canus*, a dog;

Incisors, from Latin *incidere*, to cut into.

The prefix "sub" means under. What is the meaning of submaxillary; of sublingual?

XXII.—THE THROAT.

210. Deglutition.—After mastication, the next step in the process of digestion is *deglutition*. Deglutition is swallowing, or the act by which the food is forced from the mouth into the stomach. This involves the passage of the masticated food back into the irregular chamber called the *pharynx* and also the process of conducting it into and through the *esophagus*, or *gullet*.

211. The Pharynx may be compared to a small hall, or court, in the interior of a house; for into it open no fewer than six distinct passages, communicating severally with the nose, the ears, the stomach, the mouth, and the lungs. It lies behind the nose and the mouth, and is directly in front of the five upper vertebræ of the spinal column. It is four or five inches in length, being widest at the side farthest from the mouth. Its walls are composed of three coats, or layers. The outside coat is composed of layers of muscles, three pairs of which are arranged circularly, while two pairs extend in a lengthwise direction. The inside coat is of mucous membrane and is continuous with the inside lining of the mouth. Between the muscular coat and the mucous coat, there is an intermediate coat of fibrous membrane.

212. When the food has been masticated and moistened with saliva, the muscles of the mouth and cheeks, aided by the tongue, collect it into a *bolus* on the surface of the tongue. Then by a peculiar motion of

the tongue it is carried backward and pressed into the pharynx. The circularly arranged muscles of the pharynx then contract, one after another, and with the aid of the longitudinal layers force it onward into the esophagus.

213. But why does not this muscular contraction force the food also into the other larger passages—the nose passage and the upper part of the windpipe, through which the air passes on its way to the lungs? Why does not the food lose its way and obstruct one or both of these breathing passages? To provide against such an accident each of these passages is closed during the act of deglutition by a peculiar valvular structure. We have already noticed the soft palate and uvula which together form a sort of partition between the mouth and the pharynx (§ 199). Now, when the bolus is drawn backward, these are elevated into such a position that they temporarily close the opening into the nose, thus forming a kind of valve. Sudden laughter at this particular time may cause the soft palate to relax, and then a portion of the food is sometimes forced into the nose. The other opening—that into the upper part of the windpipe—is closed by a leaf-shaped valve called the *epiglottis*, which allows nothing to pass through except the air on its way to or from the lungs.

The two smaller tubes which communicate with the ears are so constructed as to prevent the entrance of any portion of the food. The esophagus, however, presents no obstruction, and into it the bolus, as we have already seen, is forced by the contraction of the muscular coat of the pharynx.

214. The Esophagus opens from the lower and

posterior part of the pharynx. It is a muscular tube about nine inches long, lying close behind the windpipe and passing through the chest and the muscular diaphragm, and opening at its lower extremity into the stomach. It also has three coats: a muscular layer on the outside; a mucous layer on the inside, and a submucous or areolar coat between these two. The muscular coat consists of two layers, an inner, which is composed of transverse fibers, and an outer, made up of longitudinal fibers.

When the food is pushed into the esophagus from the pharynx it passes beyond the control of the will, and the remainder of the operation of deglutition is entirely involuntary. The muscular fibers of the esophagus, contracting from above downward, force the food through that passage and into the stomach; and thus the act of swallowing is completed.

215. The Use of Tobacco is one of the most common causes of diseases of the mouth and throat. We have already noticed how alcohol injures the salivary secretions, produces a dryness of the throat, and occasions an unnatural and unquenchable thirst. Tobacco also causes a morbid thirst, and in this way frequently leads those who use it to indulge in alcoholic drinks. Very often the continued habit of smoking produces a troublesome disease called *smoker's sore throat*, which can be cured only after the use of tobacco has been discontinued. This disease sometimes extends beyond the throat, and by affecting the ears produces deafness. A still more dreadful disease, which can be traced to the same cause, is *tobacco cancer*, which usually affects the lips, mouth, or throat. This disease, which is

practically incurable, seldom afflicts any except smokers, and occurs only in users of tobacco.

216. The Use of Alcoholic Liquors, besides injuring the salivary glands, causes various disorders of the mouth and throat. The delicate mucous lining of these passages is irritated by contact with the liquid. This irritation if continued may at length cause catarrhal inflammation. Dr. Mackenzie, a leading authority on diseases of the throat, asserts that the worst cases of chronic catarrh of the throat are generally the result of strong drink. The mouth of a person addicted to the alcohol habit is generally pasty and foul, the tongue is somewhat swollen and its upper surface is covered with a yellowish, furry coating. In confirmed drunkards the tongue is usually diminished in size, it is sometimes red, sometimes pale, and is often smooth from the shrinkage or absorption of the delicate papillæ (§204).

Why is alcohol so harmful to the mucous lining of the mouth, tongue, and throat? Its nature is such that it invariably deranges the natural action of all the tissues with which it comes in contact. It interferes with the growth, the breaking down, and the removal of the cells composing these tissues (§14). If pure alcohol is brought into contact with a fresh wound it produces a painful, smarting sensation; if it is held in the mouth for a short time it causes at first a burning sensation and then a partial loss of feeling, showing its benumbing influence upon the tissues. It is not hard to understand, therefore, that when the delicate mucous membrane of the throat is repeatedly exposed to contact with this destructive agent, it becomes at first irritated, then inflamed, and finally seriously diseased.

XXIII.—THE STOMACH.

217. The Stomach is the principal organ of digestion. It is the most dilated part of the alimentary canal, and is placed transversely across the upper part of the abdominal cavity immediately below the diaphragm. It is of a peculiar and irregular shape, its large end being toward the left side of the body. It is from twelve to fifteen inches in length and about four

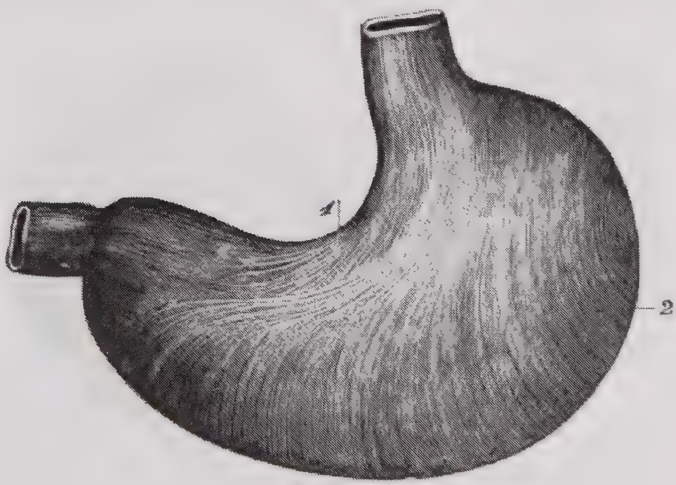


FIG. 96.—THE STOMACH.
Outside view, showing the directions of the muscular fibers.

inches in width at its widest part. Its capacity is usually about five pints. When empty it is flattened and its walls lie in contact with each other.

218. Orifices.—The opening from the esophagus is at

the greater or *cardiac* end of the stomach—that is, toward its left-hand extremity. But this opening lacks two or three inches of being exactly at the end. It is called the *cardiac orifice*. At the opposite and much smaller end of the stomach there is another opening called the *pyloric orifice* or the *pylorus*, which leads into the small intestine. From the convex border or greater curvature of the stomach there hangs a fold of peritoneum called the *omentum*, which covers the other abdominal organs like an apron.

219. But what is *peritoneum?* It is a tough serous membrane which lines the abdominal cavity and is reflected upon the viscera or contents of the abdomen.

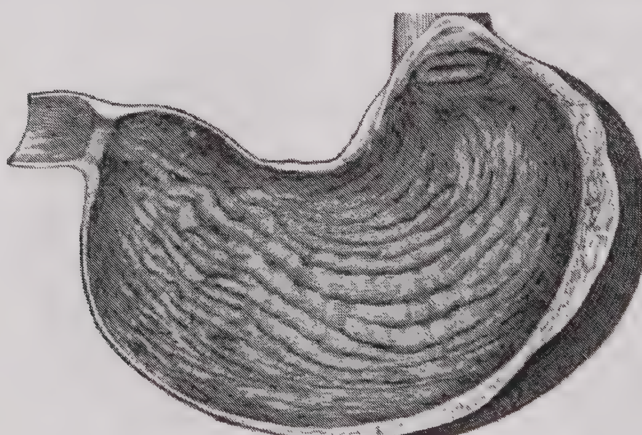


FIG 97.—SECTION OF THE STOMACH, SHOWING THE INTERIOR.

From this fact the abdominal cavity is sometimes called the *peritoneal* cavity.

220. **Coats.**—The wall of the stomach has four coats: a serous, or peritoneal, a muscular, an areolar, and a mucous. The *serous coat* is a process of the peritoneum, and consists of fibers of white, inelastic tissue

mingled with elastic fibers. The surface of this tissue, as of the entire peritoneum, is very smooth and thus facilitates the free movements among each other, of the organs in contact with it and which the peritoneum invests. The *muscular coat*, which lies directly beneath the serous, consists of three layers of fibers, a longitudinal, a circular, and an oblique.

The *areolar coat* or layer consists of areolar tissue, and lies between the muscular and mucous layers.

The *mucous layer* or inner coat consists of a soft, thick, velvety membrane of a pinkish color, large enough to line the interior of the stomach when it is fully distended. When the stomach is empty, this membrane lies in numerous folds called *rugæ*.

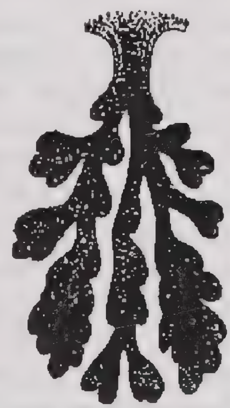


FIG. 98. — A GASTRIC GLAND (very highly magnified).

221. In the mucous coat of the stomach there are numerous minute depressions, or pits, varying from 1-200 to 1-100 of an inch in diameter. The surface of it is covered with a layer of epithelium. The mucous coat is thickest near the pyloric end, where it is about 1-12 of an inch thick. In the sides and bottoms of the pits in this membrane the microscope discovers innumerable rounded orifices which are the mouths of minute secreting glands of the class called *racemose*. These glands are found throughout the stomach except at the pyloric end, and are known by the special name *gastric glands*. They secrete a fluid called the *gastric juice*, and are active only during the process of digestion. The gastric juice is the digestive

fluid of the stomach. It is acid in reaction, and its active principle is *pepsin*.

222. Digestion in the Stomach.—We have already traced the food from the mouth cavity to the lower end of the esophagus, where it enters, through the cardiac orifice, into the stomach. Let us now see what becomes of it in the stomach.

In times of rest, that is when no food is present, the mucous membrane of the stomach is of a pale red color. But let food be introduced and a change at once takes place. The membrane becomes charged with blood, and consequently turns to a deep red color. Drops of gastric juice begin to appear at various points, and these soon increase in number and size until the fluid is poured out in streams into the interior of the stomach. A regular series of contractions and relaxations begins now to take place in the muscular coat of the stomach, and a kind of churning movement is produced, first from left to right, then from right to left. This movement leads to a thorough admixture of the food with the gastric juice. From the time the food enters the cardiac orifice until it is discharged through the pylorus, this action continues. The contractions are slow, requiring from one to three minutes for each complete movement. When the food has been in part liquefied by the chemical action of the gastric juice, and the remainder reduced to a semi-liquid mass, the gastric juice ceases to flow, and the muscular contractions of the stomach force the remaining food out through the pyloric opening into the *small intestine*. The food has now become a grayish, liquid mass, and it is called *chyme*.

223. Action of the Gastric Juice.— What is the

gastric juice, and what is the nature of the change which it causes to take place in the food?

It is a thin, clear fluid of yellow or amber tint, and it always has a strongly acid reaction. It contains various chemical compounds in small proportions; but its most important constituent is an organic principle called *pepsin*, which substance is peculiar to gastric juice and gives to it its digestive properties.

Gastric juice contains still another principle which gives it its acid reaction, and which is necessary to its proper digestive action. This is supposed to be hydrochloric acid.

224. The gastric juice does not act upon all parts of the food in the same way, and so there is nearly always more or less food which passes through the stomach without being digested. Animal food is more digestible than vegetable food, and albuminous portions of meat are readily digested in the stomach; the fatty portions, however, are not digested there but sent to the small intestine. Bread, potatoes, and pastry are digested partly in the stomach and partly in the small intestine. The starch in the food is not digested by the gastric juice; but we have already learned that the saliva converts a part of it into sugar before it leaves the stomach. All albuminous substances are readily acted upon and digested in the stomach. The gastric juice will entirely dissolve the coagulated white of egg. As a general rule substances are said to be easily digested if they are acted upon readily by the gastric juice and are required to be but a short time within the stomach.

225. The Pyloric Orifice is so constructed as to prevent the food from being passed out of the stomach

too rapidly or too soon. Around this orifice is a thick circular ring of muscular tissue, covered by mucous membrane. As the stomach digestion becomes completed, this muscular tissue relaxes and gradually permits the undigested portion of the food, as well as the chyme, to pass through the pylorus into the small intestine, where another step in the process of digestion is carried on.

226. Alcohol in the Stomach.—The effects of alcoholic drinks upon the delicate mucous lining of the mouth and throat have already been observed. It is natural to suppose that these drinks when taken into the stomach have a similar irritating influence upon the inner coating of that important organ. Not only is this the case, but the injurious effects which follow are much more serious and far-reaching. The mucous lining of the stomach becomes congested and an unhealthy viscid mucus is produced which, by its presence, prevents the proper secretion of gastric juice, and therefore interferes with the digestion of the food. Further than this, alcohol has a deleterious effect upon the gastric juice itself. Gastric juice, when mixed with a small quantity of water, has a milky white appearance. If alcohol be added to this solution the white part is precipitated to the bottom. This is pepsin, the active principle of gastric juice. In a somewhat similar way alcohol acts on the gastric juice in the stomach. The pepsin is rendered powerless, and the remaining part of the gastric juice cannot digest the food. If the quantity of alcohol taken into the stomach is considerable, the process of digestion must stop until it has been removed. Frequently the presence of alcohol in the stomach becomes so offensive

that nature removes it from the system by producing a fit of vomiting. Of all the causes of indigestion the drinking of wine, beer, or other alcoholic liquors is one of the most prominent.

One of the peculiar physical qualities of alcohol is that when placed in contact with the surface of certain of the animal tissues it is quickly absorbed by them. It is but very slightly if at all absorbed by the unbroken skin; but the mucous lining of the alimentary canal takes it up very readily, and it is by way of the veins and other minute vessels of this membrane that alcohol is generally conveyed into the blood and thence into the various structures of the human system. The greater part of the alcohol that is taken into the stomach is thus absorbed by the walls of that organ, and very little of it passes through the pyloric orifice into the small intestine. Its effects upon the stomach are such as to produce various diseases. The lining membrane being subjected to repeated irritation, it becomes permanently congested, and thus sour stomach, heartburn, nausea, and vomiting often occur. The mucous membrane frequently becomes diseased. Red or bluish patches appear in the part next to the cardiac orifice; the veins which permeate the membrane are swollen to an unnatural size; and the interior surface of the stomach becomes covered with a thick, ropy, ill-smelling mucus.

If the use of alcohol is continued, other changes take place. The appetite fails. Food becomes distasteful. There is an uneasy craving in the region of the stomach. From this the individual seeks relief by drinking more liquor, which only aggravates the distressing symptoms.

227. The Use of Tobacco is another common cause of indigestion. The habit of spitting, so universal among tobacco users, causes a great waste of saliva. The consequence is that not enough saliva is mixed with the food, and digestion is made difficult. Tobacco users are apt to have coated tongues, foul breaths, and as already stated, dry mouths and throats. These are all symptoms of a disordered condition of the digestive organs.

XXIV.—INTESTINAL DIGESTION.

228. The Small Intestine.—The intestinal canal, which forms the last division of the great alimentary canal, is composed of two parts, the small intestine, and the large intestine.

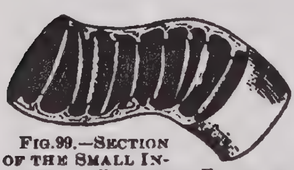


FIG. 99.—SECTION OF THE SMALL INTESTINE, SHOWING FOLDS OF THE LINING MEMBRANE.

The small intestine is a cylindrical tube which reaches from the pyloric orifice to the commencement of the large intestine. It is about twenty feet in length. There are no distinct lines of separation upon the small intestine, but it is usually described as being composed of three portions—the *duodenum*, the *jejunum*, and the *ileum*. These three portions of the small intestine differ slightly, one from another, both in structure and in functions.

FIG. 100.—SMALL PORTION OF THE MUCOUS MEMBRANE FROM THE LOWER PART OF THE ILEUM

229. The duodenum is the portion which extends for about nine inches from the pylorus. This portion of the small intestine is wider than the pyloric end of the stomach and also much wider than the jejunum.

The jejunum comprises about two fifths of the remainder of the small intestine, and the ileum the remaining three fifths.

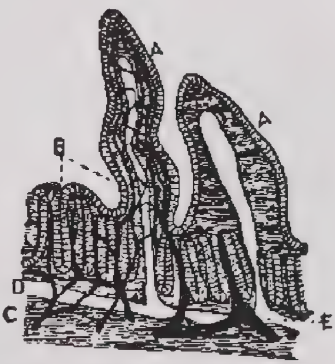


FIG. 101.—SECTION OF VILLI OF SMALL INTESTINE.
A, Villi. B, Secreting glands. C, Muscular layer. D, Lacteal. E, Artery.

The walls of the small intestine, like those of the stomach, consist of four coats — a serous, a muscular, an areolar, and a mucous.

The serous coat is derived from and is a continuation of the peritoneum (§219). The muscular coat consists of two layers of muscular fibers, one circular, the other longitudinal. The areolar coat lies between the mucous and the muscular coats. It is permeated by minute blood vessels, small branches of which pass into the mucous membrane.

The mucous membrane, or interior coat, is soft and highly vascular—that is, it contains numerous blood vessels and lymphatics. The inner surface of this coat is thrown into many transverse folds, which, as would be supposed, greatly increase the interior surface of the intestine, and therefore present a much more extensive surface for the digestion of the chyme. These folds are larger and more numerous in the

duodenum, where most of the process of intestinal digestion is carried on.

230. The Villi.—A further examination of the mucous membrane brings to view numerous small projecting processes, called *villi.* The villi are packed closely together throughout almost the entire length of the intestinal canal. They vary in length from 1-48 to 1-24 of an inch, and are of different shapes, some being cylindrical, some filiform, some conical, and others club-shaped. Each villus is invested by a cap of epithelium, which consists of columnar cells, compactly arranged side by side.

FIG. 102.—SECTION OF THE WALL OF THE SMALL INTESTINE. (Magnified.)

231. In the center of each villus, one or perhaps two minute *lacteals*, or *chyle vessels*, are situated. The lacteals begin by dilated extremities near the apex of the villus, and extend to the submucous coat, where they become continuous with larger branches which finally connect with the main lymphatic vessels of the lymphatic system. In the sub-mucous, or areolar coat of the duodenum, are small glands which resemble the mucous and salivary glands, and open by minute ducts upon the inner surface of the mucous membrane. These are called the *glands of Brunner*, from the name of the person who first described them. Throughout the small intestine are

tubular glands called the *follicles of Lieberkühn.* They consist of minute tubes closely packed together in the intestinal mucous membrane. They are very numerous, and secrete a fluid called the *intestinal juice*, which is of great importance in the digestive process.

232. The Liver.—Connected with the small intestine are the liver and the pancreas, large glands which secrete other fluids necessary to the digestive process. The liver is the largest gland in the body, weighing from three to four pounds. It is situated immediately below the diaphragm, and upon the right side of the body. Its chief function appears to be the secretion of

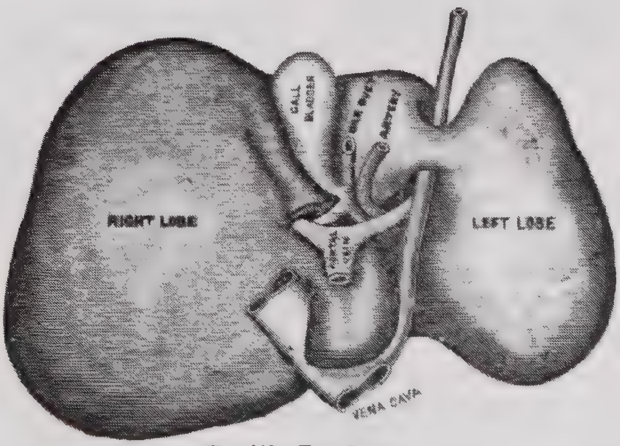


FIG. 103.—THE LIVER.

bile, but it performs the further office of effecting important changes in the blood which passes through it.

The color of a healthy liver is dark reddish-brown. It is composed of secreting cells and a network of nerves and blood vessels, all bound together by connective tissue, and the whole organ, or gland, is enveloped in peritoneum.

233. Lobules.—The liver, to the naked eye, appears to be marked out into a number of small areas called *lobules.* These lobules are of irregular forms, and vary in size from 1-20 to 1-10 of an inch in diameter. Each lobule is itself a liver in miniature. It consists of hepatic cells, a network of small blood vessels, bile ducts, and other minute structures. It is separated from the surrounding lobules by larger ducts and blood vessels and a thin stratum of connective tissue.

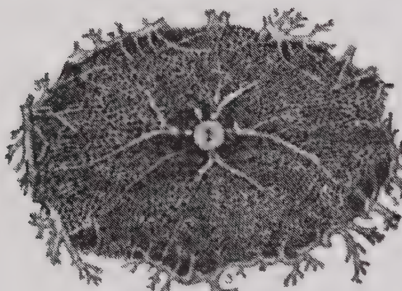


FIG. 104.—TRANSVERSE SECTION OF A LOBULE.

234. Lobes and Vessels of the Liver.—The under surface of the liver is traversed by five fissures, which divide the organ into five parts, called *lobes*, each being composed of a great many lobules. The lobes differ widely from one another both in shape and size.

There are five sets of vessels connected with the liver; these are the *hepatic artery*, the *portal vein*, the *hepatic vein*, the *hepatic duct*, and the *lymphatics.*

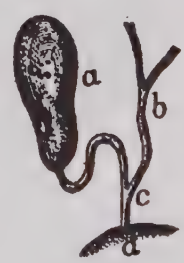


FIG. 105.
a.—Gall bladder.
b.—Hepatic duct.
c.—Common bile duct.
d.—Duodenum.

235. Bile, the secretion of which is the liver's chief function, is a somewhat viscid fluid of a golden-brown color, and having a faintly alkaline reaction.

236. The secretion of bile by the liver is going on constantly, and when there is no food in the small intestine to be digested, it is stored up in the

gall bladder, a small, pear-shaped sac on the under surface of the right lobe of the liver. From the neck of the gall bladder there issues a duct which, after a course of about 1½ inches, unites with the hepatic duct, and forms the common bile duct. The gall bladder is about three inches in length, and has a capacity of about one ounce. The common bile duct, as we have already noticed, opens into the duodenum, and the bile passing through it is there emptied into the small intestine.

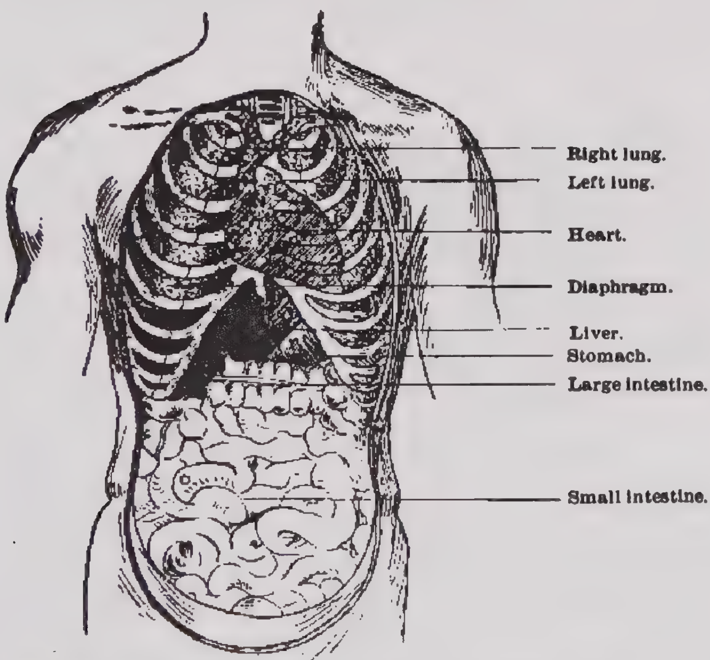


FIG. 106.—RELATIVE POSITION OF THE INTERNAL ORGANS.

237. The Pancreas.—The pancreas is a glandular organ lying along the convex border of the stomach and close to the posterior wall of the abdominal cavity.

Its length is about seven inches; its greatest width about an inch and a half; and its thickness about three quarters of an inch. A duct about one eighth of an inch in diameter extends along the body of this gland and unites with the common bile duct, not far from where it enters the duodenum. There is also a second and smaller duct which opens directly into the duodenum about an inch above the main duct.

238. In its structure, the pancreas bears a strong resemblance to the parotid and submaxillary glands, and on account of this similarity was formerly known

FIG. 107.—THE PANCREAS.
1, 2—Duct of Pancreas. 3.—Duodenum.

as the "abdominal salivary gland." It secretes a clear, watery, alkaline fluid called the *pancreatic juice*, which is of great importance in the process of intestinal digestion.

239. Diseases of the Liver.—The liver is subject to many disorders and diseases, most of which are the direct results of errors in diet or general hygiene. Excessive heat, intemperate eating or drinking, lack of proper exercise, malaria, and indulgence in alcoholic

liquors are the most frequent causes of disease of this organ. Any disorder of the liver seriously interferes with the general health. A diseased liver cannot rightly perform its functions, and consequently the life processes dependent upon it are arrested or retarded.

240. How Alcohol Affects the Liver.—When alcohol is absorbed from the stomach a large portion of it finds its way into the portal vein which carries blood to the liver. Next to the stomach, therefore, the liver is more directly exposed to the action of this poison than any other of the internal organs. Many serious disorders which sometimes affect the entire system are the results of this cause. Of these, congestion of the liver is one of the most common. Sometimes a deposit of fibrous tissue is the result, the fibrous tissue taking the place of the liver substance and causing that organ to become small and shriveled, hardened, and covered with small elevations, which give it the name of "hob-nailed liver." This affection is attended with much distress, often interfering with the liver's natural functions to such an extent as to end in death. Another disease caused by alcohol is fatty degeneration of the liver. Fat globules accumulate in the lobules and liver cells, causing the latter to become broken up and useless, and interfering to a greater or less degree with the proper secretion of bile. This is followed by imperfect digestion and other disorders, some of which are of the gravest character.

241. The effects of alcohol upon the stomach and liver become apparent in the parts immediately connected with them. The peritoneum becomes loaded with a useless accumulation of fat, and a rotundity of the

body is produced which is sometimes mistaken for evidence of health. This is very common among beer drinkers. The pancreas frequently becomes enlarged and softened; occasionally it is shriveled, its surface becomes uneven, and its color is changed to a brown or a deep yellow tint. Of course these changed conditions of this important organ must affect to a greater or less degree the quality of the fluid which it secretes, thus interfering with the digestive process in the small intestine, and impairing the health of the whole body.

242. What is this Digestive Process in the Small Intestine?—We have learned that after the food has been partially digested in the stomach it passes through the pyloric orifice into the small intestine. It is then a thick, creamy mass called *chyme* and is ready to undergo the further changes which are necessary before it is prepared for absorption into the circulatory system.

While the food is still in the stomach, the pancreas and the small glands in the mucous coat of the small intestine are excited to increased action. The liver, in the interval since the last meal, has secreted a quantity of bile which is now stored up in the gall bladder awaiting the time of use. And so, as soon as the chyme begins to pass from the stomach into the duodenum, the orifice of the bile duct relaxes and there is a flow into the small intestine of both bile and pancreatic juice. The intestinal juice from the small glands of the intestine is also mixed with the chyme. These various secretions, having an alkaline reaction, soon neutralize the acid qualities which the chyme has heretofore possessed, and cause it to be changed into a white, opaque, milky fluid. This fluid is called *chyle.*

It is the result of many distinct processes, and is composed of many and various ingredients.

243. The Chyle.—We have traced the course of the food and its changes, from its entrance into the mouth until it finally becomes chyle in the small intestine. It must be remembered, however, that not all that passes into this latter chamber is food. A considerable portion of it consists of the various secretions that have been poured into the alimentary canal during the process of digestion. Indeed, the aggregate weight of these secretions usually far exceeds that of the food itself.

244. There are certain portions of the food, too, that never reach the small intestine and hence are never changed into chyle. These consist for the most part of liquids and of such substances as are the most easily acted upon by the gastric juice and are therefore completely digested in the stomach.

If they never reach the small intestine, what, then, does become of them? Do alcoholic liquors which have been taken into the stomach form any part of the chyle? What becomes of the alcohol before it reaches the small intestine (§ 226)?

The rugae or folds of the inner coat of the stomach are studded not only with gastric glands but with blood vessels that become charged with blood during the process of digestion. Those portions of the food just alluded to, and also certain other portions which are easiest and soonest digested, are, by a peculiar process, not fully understood, absorbed or taken up by these minute vessels and mixed with the blood in the veins. This is known as *stomach absorption* (§ 259).

245. There are still other portions of the food which

do not become a part of the chyle. What are they? They consist of such substances as, for any reason whatever, have not been digested in the stomach and cannot be digested in the intestines. There is nearly always some indigestible matter in the food; often, too, on account of some defective action during the digestive process, matter which would otherwise be readily converted into chyle remains partially unchanged. Such substances are unfit to aid in the nourishment of the body and are therefore carried onward into the large intestine and finally expelled from the body.

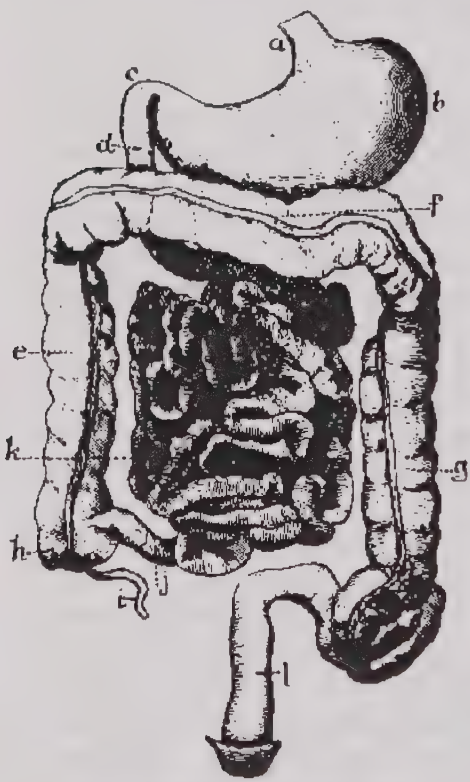


FIG. 108.—STOMACH AND INTESTINES.
a, cardiac orifice; b, greater curvature; c, pylorus; d, duodenum; k, jejunum; j, ileum; h, cæcum; i, appendix vermiformis; e, f, g, colon; l, rectum.

246. The Large Intestine. — Properly speaking, the large intestine is an excretory organ —and yet it performs important functions as one of the digestive organs. It is much shorter than the small intestine, its length being about five feet; it is also much larger,

its diameter when distended being about two and one half inches. Like the small intestine it is composed of three parts with no very distinct line of separation between them. These three parts are the *cæcum*, which forms the dilated beginning of the intestine; the *colon*, which is the longest of the three parts; and the *rectum*, which may be regarded as the terminal segment of the alimentary canal.

The cæcum lies below the ileum, or third division of the small intestine. The ileum does not open into its end, as might be supposed, but into the side of the large intestine at the junction of the cæcum and colon. Below this point the cæcum forms a *cul de sac*, the lower end being closed, but the upper opening freely into and being a continuation of the colon.

247. Attached to, and opening on the inner and posterior wall of the cæcum is a slender, hollow prolongation, about the size of a goose quill and from three to six inches in length. This peculiar formation is called the *appendix vermiformis* (Fig. 108). It belongs to that class of structures called useless tissues, for so far as can be discovered, it performs no useful function whatever. It is, however, very susceptible to inflammation, and when so affected it becomes the seat of the painful and dangerous disease called appendicitis. In many cases the prompt removal of the appendix vermiformis from the body is the only means of cure.

248. The large intestine lies in the abdominal cavity in the form of an arch, the middle or transverse portion of the colon being the upper part. The cæcum forms its right pillar, and the rectum its left. The

cæcum and colon are not, like the small intestine, a cylindriform tube; but they are composed of three rows of *sacculi*, or irregular dilatations, divided from one another by muscular bands running lengthwise with the intestine. The sacculi in each row are separated by muscular tissue similar to that which forms these bands.

249. The coats of the large intestine are four, serous, muscular, areolar, and mucous. But the serous coat only partially invests the rectum, and disappears entirely in the lower part of that division. Throughout most of the length of the large intestine the mucous membrane which forms the inner coat is covered by a layer of columnar epithelium. Here are numerous secreting glands set somewhat closely together and separated by a kind of retiform or net-like tissue. Numerous blood vessels also penetrate this coat and ramify upon its surface.

250. Although it is in the small intestine that the digestion may be said to be completed, and although it is there that the chyle attains its proper consistency and composition, yet it really remains for the large intestine to perform what may be called the finishing touches in the digestive process. Some of the food, no doubt, which was only partially changed in the other divisions of the alimentary canal, is here completely digested and absorbed by the vessels which ramify through and upon the mucous coat. Chyle which has failed to be absorbed during the long passage through the small intestine is here taken up; and the indigestible substances which were mixed with the food are pushed onward into the rectum and finally excreted.

XXV.—A REVIEW OF DIGESTION.

251. The Secretions that Aid in Digestion.—Now let us see if you can name the different secretions which become mixed with the food during its digestion.

First, the greater part of the food that is taken into the mouth and masticated is mixed with the secretion from the parotid, the submaxillary, and the sublingual glands. What is it?

Second, the food is also mixed with the secretion of the small glands situated in the mucous membrane of the mouth. What is it?

Third, it is mixed with the secretion from the gastric glands. What is it? This secretion contains, as will be remembered, the active principle of stomach digestion. What is it called?

Fourth, a secretion from the liver is poured into the duodenum to become mixed with the chyme. What is it?

Fifth, a similar secretion from the pancreas is also poured into the duodenum. What is it?

Sixth, the secretion from the glands in the small intestine performs its part in converting chyme into chyle. What is it called?

Make a list of all these secretions.

252. The Changes that Take Place.—But the food, besides being mixed with these various secretions, has at different stages of the digestive process, undergone many important changes, both mechanical and chemical. Describe them, beginning with mastication.

The albuminous portions of the food have been quite fully digested in the stomach.

In the duodenum the oils and fats have been broken up into a fine emulsion; the conversion of starch into sugar, which process was begun by the saliva, has been completed by the pancreatic juice; cane sugar which passes into the duodenum is here changed into grape sugar.

Is starch soluble in water? Why is sugar more easily absorbed than starch would be?

What is an emulsion?

Why must the oils and fats be emulsified?

253. The Organs of Digestion and their Parts.—Name in their order, from above downward, the parts of the alimentary canal.

Name in their order the various glands connected with the alimentary canal.

Name the secretion formed by each of these glands, and describe its functions.

How many coats have the walls of each division of the alimentary canal? Name each coat and describe its structure.

What is there peculiar about the inner coat of the stomach; the inner coat of the small intestine?

What are the two openings into the stomach called? Where are they situated? Which division of the alimentary canal is the longest?

What is insalivation? What is mastication? What change takes place in the food by mastication? What is the number of the teeth? What are the different parts of the tooth called? What is in the interior of the tooth?

What are carnivorous animals? What is peculiar about the teeth of grain-eating animals?

What part does the tongue perform in digestion?

What organs are connected with the act of deglutition? Why does not food pass into the trachea; into the nose passages?

How long does food remain in the stomach?

What muscle lies between the stomach and the chest cavity?

What is the digestive fluid of the stomach? Where is it secreted?

What digestive fluids act in the small intestine? Where is each of them secreted?

Describe the liver. Describe the pancreas.

Why is it necessary that food should be digested?

Why are some persons afflicted with indigestion?

XXVI.—ABSORPTION.

254. What Becomes of the Food after its Digestion. —We have learned how, after undergoing a variety of processes, both mechanical and chemical, the food is finally digested, or reduced to a fluid state, in which condition, being mixed with the digestive fluids, it is called *chyle* (§ 242). Were it to remain in this condition, merely passing through the alimentary canal, it could perform no useful purpose and would be wholly valueless as a supporter of life. The process of digestion is only an act of preparation by which the food becomes fitted to perform the office for which it is intended—that of nourishing and renewing the vital tissues. In order now that it may properly perform this function and supply nutriment to the entire

system, it is evident that it must be removed from the alimentary canal and some portion of it carried to every part of the body howsoever remote and howsoever minute it may be.

255. But how shall it be carried? The blood which flows to and through every tissue will carry it. The food must become an ingredient of the blood and remain so until it is used in the construction of new cells to replace those which have died and been removed, or to increase the bulk and strength of certain bodily structures. The process by which the nutritive food is transferred from the alimentary canal to the blood vessels is called *absorption*.

256. So long as the food was in a solid state its absorption was impossible; but being digested or reduced to a liquid form, the process is easy. Some ingredients of the food are in a fluid state when they enter the alimentary canal; some are digested and converted into fluids at quite an early stage in the stomach. Except in the case of those which require some further chemical or physical changes, it is unnecessary that such ingredients shall pass onward into the intestines before being absorbed. They are therefore transferred directly from the stomach to the blood vessels.

257. Stomach Absorption.—The mucous, or interior coat, of the stomach, like that of the intestines, is penetrated by a network of minute veins and capillaries which lie so close to one another that the entire surface seems covered with them. While digestion is going on, these vessels are so charged with blood that the inner surface of the membrane, which before was a pinkish color, now becomes a deep red. Only a

thin partition, consisting mainly of the delicate wall of the blood vessel, intervenes between the fluid food and the liquid blood. How shall the fluid food pass through this partition and become an ingredient of the blood?

258. We shall understand this better if we first perform a few simple experiments.

Experiment 1.—Tie a piece of bladder over one of the open ends of a glass tube. Pour into the tube a solution of sugar, filling it to the depth of two or three inches. Now suspend the tube, the upper end being left open, in a vessel of water, and observe what will take place. The liquid in the tube will soon begin to rise, being increased by the water passing through the membranous bladder tissue.

Experiment 2.—Fill a bladder with water and suspend it in a vessel containing a solution of sugar. A part of the water will pass through the bladder and increase the bulk of the solution. Try similar experiments with other fluids of different densities, and observe the result.

Experiment 3.—Take two saline solutions differing in strength and composition, and let them be separated by the wall of a bladder or by some other animal membrane. Both fluids will pass through the membrane, flowing in different directions, but one will pass more rapidly than the other.

259. This passing of fluids through animal membranes to become mixed or diffused with one another is called *osmosis.* If the passing is from without inward, it is called *endosmosis*; if it is in the opposite direction it is called *exosmosis.*

It is by the curious process of endosmosis that a

portion of the fluid foods is absorbed directly from the stomach into the blood vessels. It is by the same process that the chyle, composed of the digested food in partial solution with the fluids which have assisted in its digestion, is transferred from the intestines into the circulation.

But not all of the chyle is absorbed directly into the blood vessels in the inner coat of the intestines. A considerable portion of it is conveyed into the circulation by a different route.

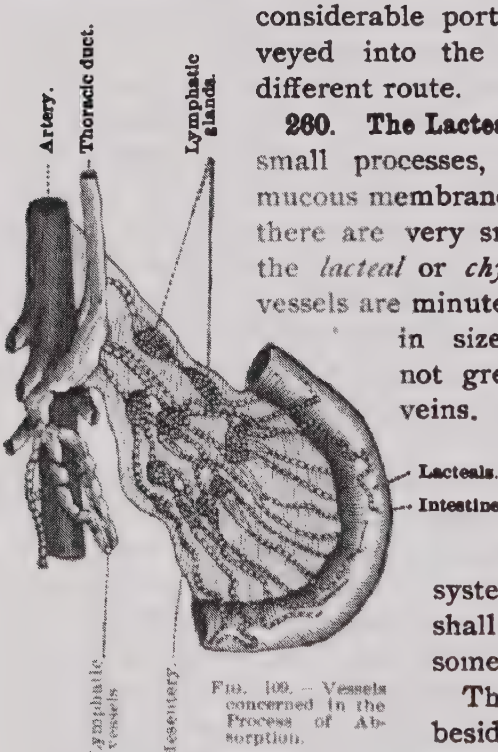


FIG. 109.—Vessels concerned in the Process of Absorption.

260. The Lacteals.—In each of the small processes, or villi, of the mucous membrane of the intestines, there are very small vessels called the *lacteal* or *chyle vessels.* These vessels are minute cylindrical tubes, in size and appearance not greatly unlike small veins. They are parts of a system of circulatory vessels called the lymph vascular system, of which we shall presently learn some interesting facts.

These lacteal vessels, besides entering into the structure of the villi, ramify and extend in all directions through the submucous tissue of the intestines, forming a network like that formed by the myriads of delicate

blood vessels in the mucous coat of the stomach. Many of the smaller vessels composing this network unite to form larger vessels, and these in their turn come together into still larger lacteals which pass through the outer or muscular coat of the intestines to the posterior wall of the abdomen.

261. The Thoracic Duct.—Beginning near the upper part of the abdominal cavity and ascending just in front of the spinal column, is a large duct, or cylindrical tube, about the size of a goose quill, called the *thoracic duct*. (See Fig. 130.) This duct is 15 to 18 inches long; it runs up to the root of the neck, and then, curving downward on the left side, empties into a large vein called the left *subclavian vein*. Its walls are composed of three coats, and it is provided with valves so arranged as to allow the fluids which pass through it to flow only in one direction, that is, upwards toward the subclavian vein.

262. Intestinal Absorption.—Now, the larger lacteal vessels, passing, as we have seen, to the posterior wall of the abdomen, communicate with and end in this thoracic duct. Let us see how these various vessels aid in the process of absorption. As the chyle in the intestine comes in contact with the villi, the greater part of it is absorbed directly by the minute blood vessels in them, just as a portion of the liquid food is absorbed by similar blood vessels in the mucous coat of the stomach. But a considerable part of the milk-like chyle passes by endosmosis into the lacteals which also ramify through the villi and mucous tissue. These carry the white fluid into the larger lacteals, and they convey it onward to the thoracic duct. During the time that this process is going on, and until

the contents of the small intestine have disappeared, the lacteals have a white appearance, due to the chyle with which they are charged. This is why they are called lacteals, from the name *vasa lactea* (milk vessels), given to them by their discoverer, Gasparo Aselli, in 1622. In the intervals between meals they are not white, but contain and carry a colorless lymph and do not differ greatly from other vessels belonging to the lymph-vascular system (§ 321).

263. Just which of the foods are absorbed directly into the blood vessels, and which through the lacteals, has not yet been satisfactorily determined; but there seems to be little doubt that sugars pass mainly into the blood vessels, and fats into the lacteals. Certain fluids, and some of the more easily digested foods, as has already been said, never reach the intestine, but are absorbed directly from the stomach into the blood vessels. It is thus that many medicines when taken into the stomach are almost instantly transferred into the circulation and carried into all parts of the system. It is thus that alcoholic liquors and other poisons find immediate access to the blood and more readily perform their deadly work (§ 226).

264. But we have not yet followed the lacteal-carried chyle to its final destination. We have seen how the smaller vessels carry it to the larger, and how the larger convey it to the thoracic duct. Being emptied into the thoracic duct, it is there combined, in greater or less proportion, with a colorless liquid called lymph, which other vessels of the lymph-vascular system have poured into the same channel (§ 323). The mixture of chyle and lymph now passes upward through the thoracic duct and is finally transferred into

the blood-vascular system by being poured into the left subclavian vein.

265. Review.—Here, now, let us suppose, is a mouthful of food—let us trace its course from the time that it passes the lips until it becomes an ingredient of the blood.

It is masticated by the ——; moistened by the ——; passed back into the —— by the ——; pressed by the —— into the upper part of the ——; swallowed, that is forced down the —— by the action of the —— muscles; passes through the —— orifice into the ——; is subjected by the stomach to a peculiar —— motion; and is thoroughly mixed with —— ——. Some of the more easily digested parts are here absorbed into the —— ——; but the greater part passes through the —— orifice into the —— ——. The food is mixed here with ——, ——, and ——.

The digestive process being finished, the food and digestive fluids compose a —— —— substance, called ——. The larger portion of the —— is absorbed directly into the —— ——. But a part is taken up by the —— which ramify through the ——.

The minute —— vessels carry it to the ——; and it is conveyed to the ——, where it is mixed with a —— called ——. The mixture flows upward through the —— ——, and is poured into the —— ——, where it becomes an ingredient of the venous blood, with which it flows onward to the heart.

Those portions which were absorbed by the more direct route, that is, through the walls of the veins in the stomach and intestine, are by more devious ways at last conveyed to the same point. The whole of the nutritive digested food is thus transferred into the

blood-vascular system. Let us leave it as it passes through the subclavian vein, and learn what the blood-vascular system is.

XXVII.—THE BLOOD-VASCULAR SYSTEM.

266. General View of the Vascular System.—The human body is traversed by a complex network of tubes, or pipes, called vessels. Some of these vessels are nearly an inch in diameter, others are too small to be seen with the naked eye, while others are of all sizes between these two extremes. In very many parts of the body they are so numerous and lie so close together that it is impossible to insert the finest needle point without striking one or more of them. These vessels are connected with and dependent upon the heart, and with it form what is called the *vascular system* (Latin, *vasculum*, a small vessel).

There are two classes of vessels, those which carry *blood* and those which carry *lymph.*

The heart and blood vessels constitute the *blood-vascular* system; the lymph vessels constitute the *lymph-vascular system.*

267. The Blood-Vascular System.—The movement of the blood in the blood-vascular system is called the circulation, and the system itself is generally known as the *circulatory system.* The organ and vessels which comprise it are called the circulatory apparatus, or circulatory organs.*

*"The vascular system is a hydraulic apparatus, possessing a pump, pipes, and valves. The heart is the pump, which works,

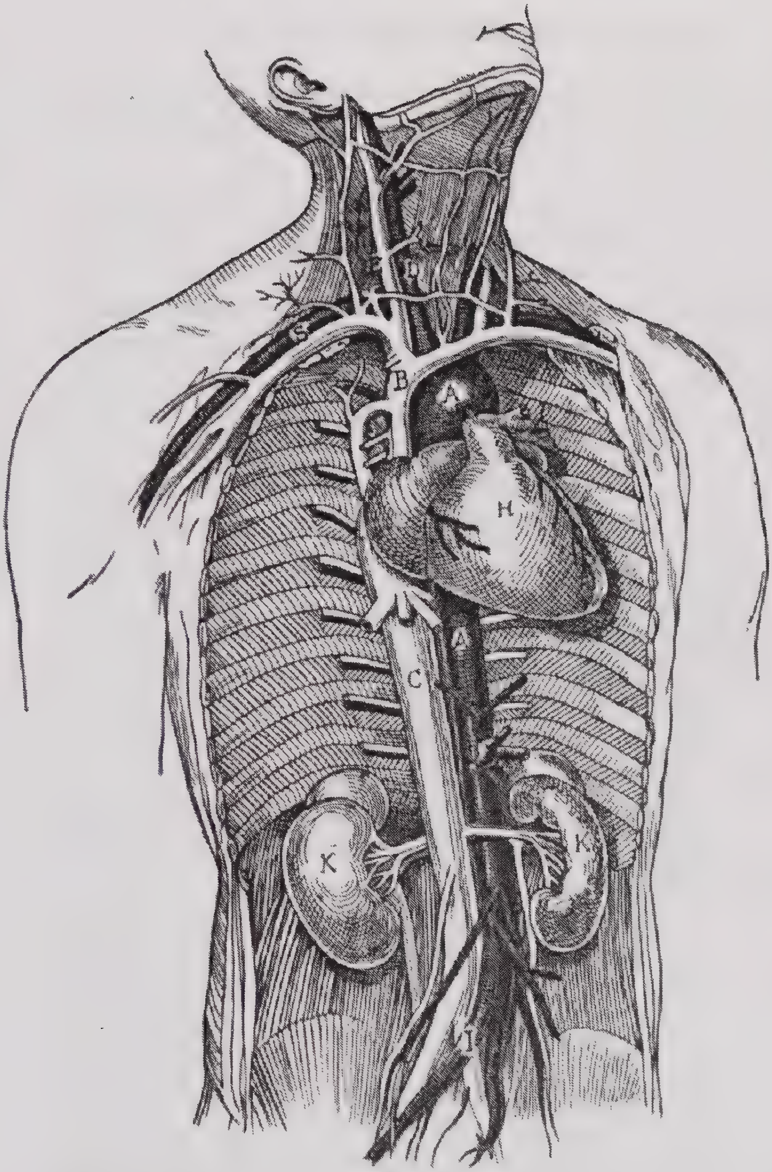


Fig. 110.—General Plan of the Heart and Large Blood Vessels.

H, Heart. A, Aorta. B, Descending vena cava. C, Ascending vena cava. D, Carotid artery. E, Jugular vein. S, Subclavian artery and vein. I, Iliac arteries and veins. K, K, Kidneys.

The circulatory apparatus consists of a central organ, the heart, and distributory organs known generally as the blood vessels.

During life there is a continuous flow of blood *from* the heart, *through* certain of the blood vessels, *to* the different parts of the body, and through other blood vessels *back* to the heart. The blood, as it thus circulates, carries nourishment to the tissues, restores broken-down cells, and removes worn out matters which are of no further use in the body.

268. A Retrospect.— Now let us look again at the course of the chyle which we left just as it entered the circulatory system (§ 265). With how many and what liquids has the digested food which comprises a part of the chyle been mixed or combined?

In what part of the alimentary canal is the chyle produced? Of what does it consist? How does it find its way into the lacteals? To what part of the body is chyle carried by the thoracic duct? Into what is it emptied?

When the chyle is emptied into the left subclavian vein it immediately becomes mixed or combined with the blood already contained in that vein.

It flows rapidly onward and passes into a much larger vein, the *descending vena cava*, by which it is carried to the central organ of the circulatory system. Let us learn something about the structure and action of this important organ.

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not by the movements of a piston, but by the contraction of its muscular walls; the vessels are the pipes which convey the contained fluid and they are provided in certain localities with valves for modifying the flow."

XXVIII.—THE HEART.

269. Description.—The heart is a strong, muscular, pear-shaped organ, situated within the thoracic cavity, or chest. It lies between the two lungs, and slightly towards the left side. Its weight in the adult is about ten ounces, and it is about the size of one's clenched fist, or five inches in length by about three and a half in breadth.

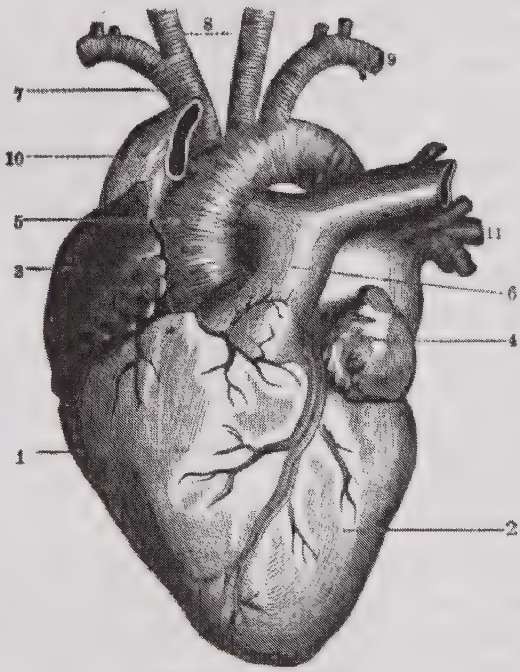

FIG. 111.—THE HEART.

1.—Right ventricle.
2.—Left ventricle.
3.—Right auricle.
4.—Left auricle.
5.—Aorta.
6.—Pulmonary artery.
7, 8, 9.—Branches of the aorta.
10.—Superior vena cava.
11.—Pulmonary veins.

It is a hollow organ, and is held in position by large blood vessels attached to its base and also to the back part of the thoracic cavity. The base of the heart lies uppermost, its apex being below. The base, being held firmly in posi-

tion, is immovable; the apex, or point, however, is freely movable, and with each beat of the heart it is moved forward and strikes gently against the front wall of the thorax. Many persons can distinctly feel this striking by placing their hand upon the left side over the heart.

270. The Pericardium.—The heart is loosely enveloped by a strong, fibrous, membranous sac, called the *pericardium*. It moves freely within this covering, and to prevent any friction or rubbing between the wall of the heart and the surface of the pericardium, there exists in the pericardial sac a small amount of clear fluid which acts as a lubricator. This fluid is called the *pericardial fluid*. Sometimes the pericardium becomes inflamed and this fluid is much diminished in quantity; in such a case the action of the heart is attended with pain and distress, due to the friction which then results.

271. Walls of the Heart.—We have elsewhere spoken of the heart as a muscular organ. It is made up almost entirely of muscular tissue. What peculiarity distinguishes the fibers of this tissue? Are they striped or non-striped? Are they voluntary or involuntary?

The muscular walls of the heart are exceedingly strong; and its alternate contraction and relaxation is attended with considerable force. The contraction of the heart is attended with much the same kind of shortening and hardening as is seen in the muscles of other parts of the body.

272. Cavities of the Heart.—We have said that the heart is a hollow organ. Nevertheless its interior is not a single chamber, as one might infer, but is made

up of four distinct chambers or cavities. First, by a muscular partition, the interior of the organ is divided into two halves or cavities, a right and a left, called respectively the *right heart* and the *left heart*. Each of these two chambers is also divided into two parts, an upper and a lower cavity. The two upper cavities are called *auricles*—a right and a left—and the two lower ones are called *ventricles*—also a right and a left. The walls of the ventricles are quite thick and are very strong, while those of the auricles are much thinner and not nearly so strong.

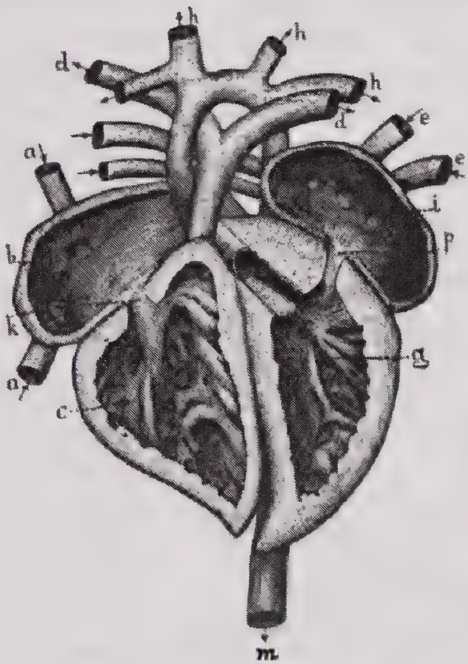

FIG. 112.—CAVITIES OF THE HEART.
b.—Right auricle. c.—Right ventricle.
i.—Left auricle. g.—Left ventricle.
k.—Right auriculo-ventricular opening.
p.—Left auriculo-ventricular opening.
a, a.—Venæ cavæ. d, d.—Pulmonic arteries.
e, e.—Pulmonic veins.
h, h, h.—Arteries. Branches from the aorta.

It is into the right auricle that the large vein—the descending vena cava—conveys its constantly flowing current of blood mixed at times with the nutritious chyle which has been absorbed in various ways from the digestive passages.

273. The Valves of the Heart.—From the right auricle

the blood flows through an opening called the *auriculo-ventricular orifice* into the right ventricle. This opening is guarded by folds of membrane which allow the blood to flow freely in one direction but effectually prevent it from returning. They thus act precisely as valves and are called, from the shape of the membranes composing them, *tricuspid valves*. Were it not for these valves, the blood in the ventricle would, at every contraction of the heart, be forced backward into the auricle, and from the auricle into the veins, and circulation would be impossible.

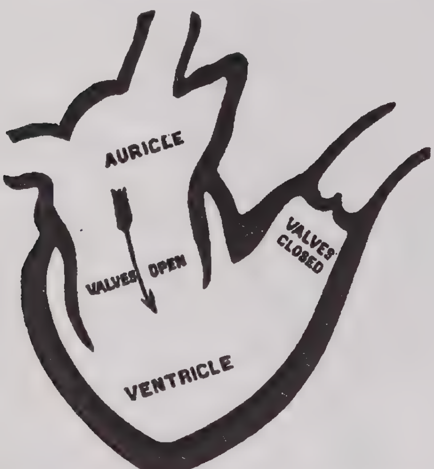

FIG. 113.—VALVES OF ONE SIDE OF THE HEART. The blood flowing from the auricle into the ventricle.

Opening from the right ventricle, there is a large blood vessel called the *pulmonic artery*, which is also supplied with valves. These pulmonic valves are so constructed as to permit the blood to flow out from the heart, but not in the contrary direction. Hence, at each contraction of the right ventricle the blood is forced from it, to be conveyed by the pulmonic artery to the lungs, where it undergoes certain changes of which we shall learn more at a later time.

Returning from the lungs through certain veins, called the *pulmonic veins*, the blood is again poured into the heart, but this time into the left auricle. Between

the left auricle and the left ventricle there are valves —called *mitral valves*, from their resemblance to a bishop's miter—which act in the same manner as the valves in the right side of the heart. They permit the blood to flow freely into the ventricle, but effectually prevent its return. Issuing from the left ventricle is a large and strong blood vessel—the largest artery in the body—called the *aorta*. At its entrance are the *aortic valves*, very similar in construction and function to the pulmonic valves on the opposite side of the heart. At each contraction of the ventricles the blood is forced through these valves into the great artery, the aorta, which, dividing and subdividing into innumerable other arteries, carries the life-sustaining fluid to every tissue in the body.

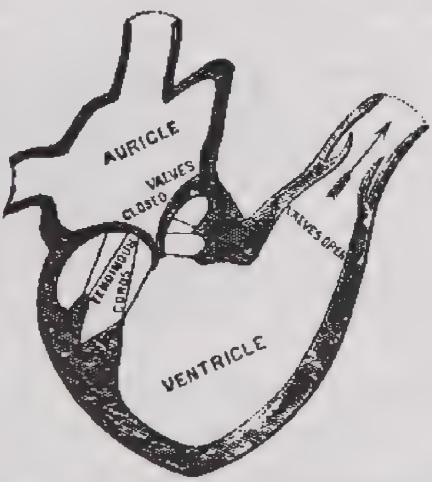

FIG. 114.—VALVES OF ONE SIDE OF THE HEART. The blood flowing from the ventricle into the blood vessels.

274. Disorders of the Heart.—Disorders of the heart are in a great majority of cases caused by some indiscretion which could have been prevented. Severe physical exertion by one not accustomed to it has very injurious effects upon the heart, and should be carefully guarded against. On the other hand, insufficient muscular exercise tends to make the heart feeble. Judicious and systematic physical exercise is the best promoter of strength because it promotes the healthy

action of the heart. Extreme heat and cold affect the heart's action, heat stimulating it, cold depressing it. It is therefore important that the body be properly clothed according to the season or the circumstances. Fits of anger, sudden fright, nervous shock, all have an injurious effect upon the action of the heart. One's emotions should be kept as much as possible under control, and excesses of all kinds should be avoided.

275. How Alcohol Affects the Structure of the Heart.—The use of alcoholic drinks often changes the structure of the walls of the heart, producing what is known as fibroid degeneration. In such cases the heart becomes larger, paler, and of a firmer consistency than in its normal condition. Masses of new fibrous tissue begin to be developed in and around the muscular fibers, and gradually to crowd them out. The walls of the heart become weakened and the heart's action is enfeebled. In the end, sudden death is likely to occur.

Another and more frequent affection produced by alcohol is that known as fatty degeneration of the heart. This fatty degeneration may occur in many of the tissues, but it has a special tendency to attack the walls of the heart. Particles of fat are deposited in the heart substance, breaking up and crowding out the muscular fibers, and gradually changing its structure until it partially loses the power of contraction. The result is that the circulation of the blood becomes feeble, the least exertion produces shortness of breath, and a hacking cough ensues. The memory is impaired, and the person becomes incapable of any active mental or physical effort. If the use of alcohol is continued, the deposit of fatty particles may be increased until the

heart loses its power and life ceases. Not only are the walls of the heart injuriously affected by the use of alcoholic drinks, but the valves also often become diseased.

276. Practical Review.—Which part of the heart is the larger, the upper or the lower?

What are the chambers on the right side of the heart called; on the left? What are the two upper chambers called; the two lower?

Is there any opening between the right and the left side of the heart? How are the two sides separated? How does the blood from the left side finally reach the right side? How many valves has the heart?

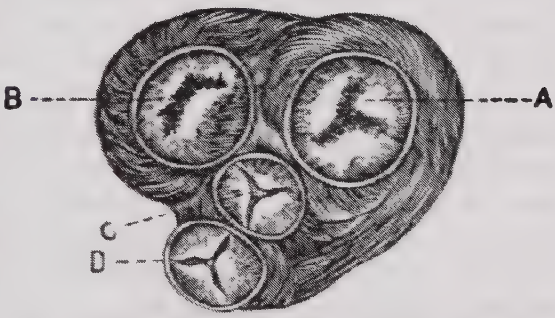

FIG. 115.—VALVES OF THE HEART.
The auricles and blood vessels are cut off close to the valves.
A.—Tricuspid valve. C.—Aortic valve.
B.—Mitral valve. D.—Pulmonic valve.

What are the vessels called which empty the blood into the auricles? What are the vessels called which receive the blood from the ventricles?

How many openings are there into the heart? How many openings are there from it?

To what part or parts of the body is the blood sent when it is expelled from the left ventricle?

Which ventricle sends the blood farthest? Which, then, is required to exert the greater force? For this reason the walls of the left ventricle are much thicker and stronger than those of the right.

Why are there no valves at the orifices where the veins open into the auricles?

Into what is the blood driven by the contraction of the auricles? Into what is it driven by the contraction of the ventricles? Which necessarily exerts the greater force, an auricle or its corresponding ventricle? Which requires the stronger walls?

277. Action of the Heart.—The capacity of the heart is about six ounces, and with each contraction this amount of blood is sent into the blood vessels. During each interval between the heart beats the same amount must, of course, be poured by the veins into the auricles. As a general rule the heart contracts and then relaxes about seventy-two times in each minute.

How many pounds of blood, upon the above calculation, pass through the heart in the course of a minute?

The weight of the blood in a healthy adult is equal to about one eighth that of his entire body. What is the amount of blood in a healthy person whose weight is 160 pounds?

Supposing that all the blood moves with the same rapidity, how much blood will pass through the heart in a day of 24 hours? How often within that time will all the blood in the body have made a complete circulation?

278. Sounds of the Heart.—Simultaneously with every contraction of the heart the auriculo-ventricular valves are closed and the pulmonic and aortic valves are opened. Simultaneously with every relaxation the pulmonic and aortic valves are closed, and the auriculo-ventricular valves are opened. By placing one's ear against the chest of another person near the region of the heart peculiar sounds may be heard occurring with

great regularity. These sounds are caused chiefly by the closing first of one set of valves, then of the other. By observing the nature of these sounds a physician is frequently enabled to determine important facts relative to the action of the patient's heart and the condition, not only of the valves, but of the entire organ itself.

279. The Pulse.—It has been stated that with each contraction of the heart a certain quantity of blood is forced into the aorta to be carried by the arteries to the various tissues of the body. Now this sudden accession of blood by the arteries causes a slight momentary expansion of their walls, and with each heart-beat there is a gentle throbbing of these vessels throughout their entire length. Place the end of your right middle finger upon your left wrist just above the ball of the thumb. What do you observe?

Count the number of times your pulse beats in a minute. With every contraction of the heart, this artery in the wrist expands suddenly and produces a pulse beat. How many times does your heart beat in a minute?

The pulse may be felt in other parts of the body wherever an artery of considerable size lies near the surface. It may sometimes be seen in the throbbing of one of the great blood vessels on the side of the neck. But, since most of the large arteries lie deeply imbedded among the muscles, there is no other place in which this can be so conveniently observed as in the wrist.

280. As a general rule, the heart of a child beats more rapidly than that of an older person; the heart of a girl beats faster than that of a boy of the same age;

posed that the mere filling of the auricles with blood from the veins acts through the nerves as a stimulus to cause the upper part of the heart to contract, sending the fluid quickly into the ventricles, where its presence causes an immediate and stronger contraction. The auricle, being relieved of its blood, relaxes, only to be quickly filled again — and thus the process is repeated quite regularly every moment of life. But, suppose that a large blood vessel is injured so as seriously to retard the flow of the fluid into the heart, or so as to allow a large part of the blood to escape from the circulation, then the chambers of the heart can no longer be filled by its stimulating current, the heart-beats become more feeble and irregular and soon entirely cease. A puncture or cutting of the heart itself produces the same result. The destruction of the nerve centers does likewise.

284. Review.—Why is the blood-vascular system so called? By what other name is it often called? Why?

What is the central organ of the vascular system? Is it a blood vessel? To what familiar mechanical device may it be likened in its action? Why?

Of what use is the pericardium?

What would be the result if the heart muscle could be controlled by the will? What other muscles besides the heart are involuntary? How does the heart differ in structure from other involuntary muscles?

How many openings are there *into* the heart, and where are they? How many openings are there *from* the heart, and where are they?

What are the vessels called which bring blood to the heart? What are those called which carry it away?

Why are the walls of the ventricles stronger than those of the auricles?

When the heart contracts, at which part does the contraction begin? Why? Which part contracts with the greater force? Why?

How does the blood in the right side of the heart finally reach the left side?

XXIX.—THE BLOOD.

285. We have already, in these chapters, made frequent mention of the blood. What is it? Is it thinner or thicker than water? What is its color? What other peculiarities are noticeable in its properties or appearance?

The blood is the most abundant fluid in the body. It is also the most important, for upon it all the processes of nutrition are dependent, and without it life could not be maintained even for the briefest period. It will be interesting to learn something about its appearance, composition, and properties.

286. Appearance of the Blood.—When examined in very thin layers, the blood appears to be transparent; but, as usually observed, it is opaque and differs in color according to its degree of purity and the blood vessels in which it is found. In the arteries of children it is of a light vermilion tint; in the arteries of adults it is cherry red, bordering upon purple. In the veins of both children and adults it is a dark bluish red, sometimes of a blackish tint. It has a peculiar odor, somewhat like that of the perspiration.

287. Composition of the Blood.—Although a fluid, the

blood consists of two different parts or elements, one liquid, the other solid. The liquid part of the blood is called *plasma*, the solid parts are the *blood corpuscles*, or *blood globules*. The plasma is almost colorless and is composed largely of water. The blood corpuscles, which are held by suspension in the plasma, are too small to be seen except with a microscope. The mixture of the blood corpuscles with the plasma is purely mechanical, like the mixture of sand or of mustard seeds with water.

Since everything, whether solid or liquid, that enters into the composition of the tissues must be carried to its destination by the blood, it follows that pure blood contains a very large number of chemical elements and compounds.

Of a given quantity of such blood, nearly four fifths of the weight is water, while the remaining one fifth consists of solid matters. The solid matters, as already stated, are contained chiefly in the blood globules or corpuscles; but there are solids which exist in a state of solution in the plasma. Among the latter is *plasmine*, which, although comprising an extremely minute proportion of the blood, yet performs a very important function (§ 289).

Iron is found in the corpuscles, where it is united with *hæmaglobine*, the coloring matter which imparts to the blood its redness. It is probably the most important of the metals contained in the body. Physiologists have also discovered minute quantities of copper, manganese, and lead, either in the corpuscles or in the plasma, or in both. Other substances are chlorine, sodium, oxygen, sulphuric acid, phosphoric acid, potassium, and the phosphates of lime and

magnesia. In certain persons and in certain conditions of the system, the blood contains more water than in others. The proportion of the various solid substances is also subject to constant variation.

288. When alcohol is taken into the stomach, how does it find its way into the blood (§ 226)? How soon after being taken is it likely to reach the heart? Having found its way into the blood, alcohol is carried by it to all parts of the body, affecting to a greater or less degree all the tissues and organs. It has a direct influence upon the composition of the blood itself. In persons addicted to the use of alcoholic drinks the proportion of water is increased, while that of the plasmine is diminished. The blood of such persons also contains free fat, which gives it a pale and sometimes milky hue. The number of blood corpuscles is diminished.

289. Coagulation.—If blood be drawn from a vein or artery it very soon begins to coagulate. It loses the liquid condition and becomes a jelly-like substance.

The coagulated substance gradually contracts; the solid matter, including the corpuscles, appears to be enclosed in a delicate network, and the liquid part of the blood is literally squeezed out between the meshes. This solid part is called the *clot;* the liquid part is called the *serum* of the blood. The serum differs in some important ways from the plasma.

What causes this coagulation or clotting of the blood? The plasmine, which existed in solution in all parts of the plasma, decomposes, when exposed to the air, and produces fibrin. This solidifies into a network so delicate that it holds the corpuscles or blood globules within its meshes, while the liquid matters

are squeezed out and escape. If, by any means, the plasmine be removed from the blood immediately upon its withdrawal from the circulation, true coagulation does not take place; but even in that case many of the minute corpuscles will sometimes adhere to one another, forming a clotty mass which somewhat resembles coagulation. A low temperature retards but does not prevent coagulation; a temperature of 150 deg. F. causes the blood to remain liquid. Coagulation takes place the most readily when the blood has about the same degree of heat which it had in the body.

This coagulation or clotting of the blood is of great importance, for its occurrence in the case of wounded blood vessels assists greatly in stopping the hemorrhage. Were it not for this peculiar property of the blood, the cutting of the smallest blood vessel might induce a flow of blood which could not be checked.

Why are persons who use alcoholic liquors more likely to bleed to death from wounds than persons who never indulge in alcohol?

290. Formation of the Blood.—Since the blood in the blood-vascular system is constantly giving up certain of its elements to be used in the repair and nutrition of the tissues, it follows that new blood must constantly be formed to take the place of that which has thus been transformed into other substances. Much of the blood, as you will have already surmised, is formed from chyle, or from the chyle in combination with the lymph. According to some physiologists no less than twenty-eight pounds of lymph and chyle are poured into the blood-vascular system daily, about one fourth of the amount being chyle. Just how much of this is converted into arterial blood, and how much is elimi-

nated from the system or changed into other fluids, no one has been able to determine.

Experiments with the lower animals have shown that blood is constantly being formed, even when no food is present in the system and there is no chyle. Blood has been taken from a dog in such quantities that the removal at that time of one or two ounces more would have destroyed the creature's life; but it was found the next day, although in the meanwhile the dog was not fed, that ten or twelve ounces could be removed without fatal effects. This is thought to prove that a portion of blood is formed independently of the food—that is, from the elements composing the body itself, or from those derived from the air that is breathed.

291. Transfusion.—In cases of abundant hemorrhage caused by accident or otherwise the supply of blood is sometimes so reduced that it is no longer capable of supporting life. Fatal results at such times have often been prevented by injecting into the blood vessels of the patient a small quantity of pure blood drawn from the vessels of a healthy and vigorous person. This process is called *transfusion of blood.*

292. The Blood Corpuscles.—Much the greater part of the solid matters of the blood consists of corpuscles, and the number of these minute globules is incomprehensible. They are of two kinds, the *red corpuscles*, or disks, and the *white corpuscles*. The red are by far the more numerous, there being several hundred of them where there is but one of the white variety. They are found in the blood of all vertebrate animals, being of a different shape in each species. By the aid of a microscope powerful enough to distinguish the form of

the red corpuscles it is therefore always possible to distinguish human blood from any other.

293. In man the red corpuscles are flattened circular discs, slightly concave on both sides. They are so small that it would require 3,500 of them, placed side by side, to extend one inch; and if they could be laid one on top of another, it would take 140,000 to make a pile one inch high. But while this indicates the average size of the discs, it is worthy of note that they are not all of the same size, even in the same individual. They exist suspended in the plasma so close together that in a cube of healthy blood measuring one twenty-fifth of an inch, there are no fewer than four or five millions of them. How great, then, must be the entire number in the human body! They are so pliable and elastic that they can pass through blood vessels having a diameter smaller than their own.

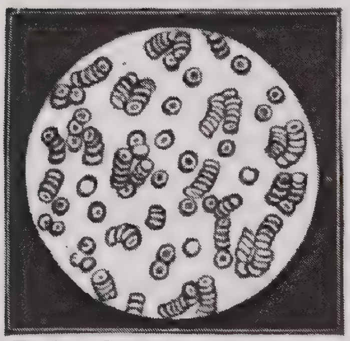

FIG. 116.—RED BLOOD CORPUSCLES. Highly magnified.

FIG. 117.
a.—Blood corpuscles of a frog.
b.—Human blood corpuscles.
Both are equally magnified.

If a solution of alcohol is dropped into a vessel containing pure blood freshly drawn from the arteries, a

change at once takes place in the blood. An examination through the microscope shows that contact with the liquor has caused the red blood corpuscles to shrink and become smaller. A similar result is no doubt produced upon the blood in the arteries when alcohol is taken into the circulation.

294. The White Blood Corpuscles, besides being found in the blood, occur also in the lymph and the chyle. Although not so numerous as the red, they are much larger. They are globular in shape, and are almost uniform in size. In some forms of disease they multiply until they seem to be almost as numerous as the red corpuscles. In their structure they resemble minute cells, having a distinct nucleus but probably no cell wall. What is a cell? The red corpuscles, having no nucleus, differ very materially in structure from the white.

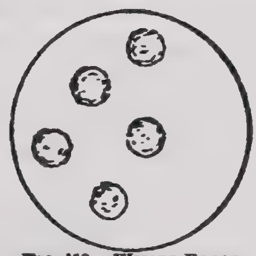

FIG. 118.—WHITE BLOOD CORPUSCLES.
As they appear when magnified.

295. The white corpuscles have several curious properties. They are able to protrude upon their surfaces delicate rounded processes which are capable of changing shape and are finally withdrawn again into the globular outline of the corpuscle. Physiologists have discovered that the white corpuscles are also able to pass through the walls of the blood vessels into the surrounding tissue. These wandering corpuscles are believed to perform an important part in many physiological processes. It is supposed that, among other functions, they exert certain influences for the prevention of disease, but how this is done has not yet been satisfactorily explained.

296. The functions of the red blood corpuscles are better understood, and they are known to be concerned in some of the most important processes of life, such as the carrying of oxygen from the lungs to the tissues. Of these processes we shall learn more as we continue our study of this subject (§ 340). It is believed by some that the red corpuscles are derived from the white; and some physiologists have claimed that they are also formed in the spleen (§ 326). Besides the corpuscles, there are in the blood other still more minute particles the nature of which has not been determined.

297. Review.—What is the most abundant fluid in the body? In what part of the body is the blood not found? Why may it be said to be the most important of all the fluids? How is it possible for one of the vital fluids to be more important than another?

Name another fluid, besides the blood, whose existence and presence is absolutely necessary to the continuance of life.

In what veins do other elements become mixed with the blood? To what part of the circulatory system do these veins conduct the elements thus introduced?

Why may the loss of blood in large quantities endanger life? Name one way in which blood may be removed from the system.

If alcoholic liquor be taken into the digestive system, how and where is a considerable portion of it transferred or absorbed into the blood-vascular system?

Name one effect which it must then have upon the plasma of the blood. What effect does it probably have at the same time upon the corpuscles of the blood? Being carried by the blood into the heart, what is its effect there?

What is your weight? About what is the weight of the blood in your body?

Of how many kinds of blood vessels have you learned? In what direction do the veins carry the blood? The arteries?

XXX.—THE BLOOD VESSELS.

298. Arteries and Veins.—At their junction with the heart the blood vessels are large cylindrical tubes; but as they proceed in their course away from the great central organ they divide and subdivide into innumerable branches which finally become too minute to be seen by the naked eye. The arteries differ from the veins, not only in the special function which they perform, but in their structure.

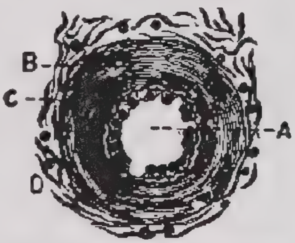

Fig. 119.—Transverse Section through an Artery.
A.—Interior.
B.—Coat of fibrous and muscular tissue.
C.—Internal coat.
D.—Outer coat. Fibrous.

299. The wall of an artery is very strong and consists of several coats or layers. The outermost coat is of connective tissue, the next is of yellow elastic tissue, the next is a muscular coat composed of involuntary muscular tissue, and internal of this is a smooth elastic membrane. Internal of the last named coat is a layer of *endothelial cells* which present a smooth surface for the flowing blood to pass over.

300. The arteries are abundantly supplied with

nerves which belong to the sympathetic nerve system and are called *vaso-motor nerves*. These nerves control the size of the arteries by causing their walls to contract or relax, thus increasing or diminishing the caliber and also the carrying capacity of the vessels. The larger arteries are, with but few exceptions, so deeply imbedded among the bones and muscles that they, with their precious freight, are well protected from ordinary accidents and from external pressure. The circulation of the blood through the arteries is quite rapid, experiments having demonstrated that it moves at the rate of twenty inches in each second, its progress being the most rapid at the time of the contraction of the heart.

FIG. 120. LONGITUDINAL SECTION OF A VEIN, SHOWING THE VALVES.

Tell of an artery which at one point lies near the surface (§ 279).

What effect does the contraction of the heart have upon the walls of the arteries? Why is this so?

301. The veins have the same number of coats as the arteries, but they are much thinner and are neither so firm nor so elastic. Within the caliber of nearly all the veins are small folds of membrane which are of such a shape as to form very perfect valves. These valves open in such a way as to allow the blood to flow in only one direction. What direction is that? They are most numerous in the veins of the lower extremities, aiding in the circulation of the blood by preventing it from being held back by its own weight.

What are the names of the two veins which empty their blood into the right auricle of the heart?

One of these veins is formed by the union of the veins of the head and of the upper part of the body; the other is formed by the union of the veins of the lower extremities and of the lower part of the body.

302. When a vein is emptied of its contents, its thin walls collapse. But not so with an artery, for its rigid walls cause it to retain its original shape. And so we understand why the ancient anatomists gave to the latter the name *artery*, or air vessel (from Gr. *aer*, air); for when, after death, the blood is withdrawn from these vessels, air enters and takes its place. As a usual thing, each artery in the general circulation is accompanied by two veins, but to this there are important exceptions.

FIG. 121.—A PORTION OF A VEIN LAID OPEN, SHOWING THE VALVES.

303. **Practical Questions.**—What is the name of the largest artery and where does it originate?

Why do not arteries have valves like the veins?

Is the blood which the venæ cavæ empty into the right auricle pure blood? Why not?

What is the color of the venous blood?

What kind of blood is carried out of the right ventricle by the pulmonary artery? Is this blood carried directly across to the left chambers of the heart? What vessels finally convey it to those chambers?

In what respects does the blood emptied into the left auricle differ from that emptied into the right auricle?

What kind of blood is carried out of the left ventricle by the aorta?

Do any of the arteries carry impure blood? Do any of the veins carry pure blood?

304. As would naturally be supposed, alcohol has a decidedly harmful effect upon the blood vessels. It has a tendency to paralyze the vaso-motor nerves (§ 300). The walls of the arteries in such case partially lose their power of dilatation and contraction, and have no longer the power properly to regulate the flow of the blood. The blood vessels generally become distended and enlarged, their capacity is increased, and too much blood is sent to certain parts. This action of alcohol is apparent in the flushed face and red nose of the habitual drinker. The constant stretching of the walls of the blood vessels causes them to grow thinner and weaker, and they occasionally become unable to withstand the pressure of the blood in them and consequently burst. Fatty degeneration of the walls of the blood vessels often occurs, weakening them and interfering with the circulation.

XXXI.—THE CIRCULATION.

305. The Pulmonic Circulation.—The blood as carried by the veins to the right side of the heart is not in a condition to perform any useful service in the body. True, it contains in solution the nutritious elements of the food that have been absorbed from the digestive system; but these elements require to be still further changed before they are fitted to enter into the composition of new cells for the sustenance or growth of the living tissues. Mingled also with this

venous blood are remnants of broken-down and useless cells, waste matter which has been removed from the tissues, and various other impurities which if allowed to remain in the system would act as poisons and be destructive to life.

How is the blood to rid itself of many of these impurities while at the same time the nutritive elements which it contains are prepared to perform their required functions? These wonderful changes are effected in the lungs, whither the blood is carried by the pulmonic arteries. The pulmonic arteries, after they reach the lungs, subdivide into countless branches which ramify in the delicate walls of the thousands of minute air cells contained in these organs of breathing. Of the manner in which the impurities are here eliminated from the system we shall speak further when we come to consider the structure of the lungs. Purification having been accomplished, the blood flows outward into minute veins, which, uniting into larger and still larger channels, finally form the great pulmonic veins. Into what do the pulmonic veins empty their blood (§ 273)?

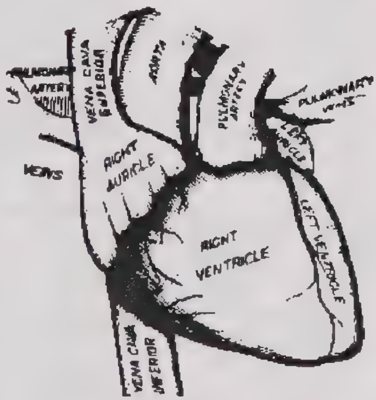

Fig. 122.—Blood Vessels Opening into the Heart.

306. The blood which flows away from the lungs is quite different from that which flows to the lungs. What has it lost? It has at the same time be-

come charged with oxygen, a life-giving element derived from the air and as necessary to the sustenance of the body as the blood itself. It still contains the nutritive principles derived from the food, but they are now in a condition to be utilized by the tissues wherever needed. It is no longer of a dark, bluish tint, but is a bright red. It is no longer the carrier of worn-out materials and poisonous impurities, but is the bearer of life-supporting, strength-giving, nutritive substances without which all vital processes would soon cease. These are the characteristics of the blood as it returns to the heart, but to its left side instead of its right. It has made the circuit of the lungs, and we call its passage through the pulmonic vessels *the lesser, or pulmonic circulation.* (See Fig. 124.)

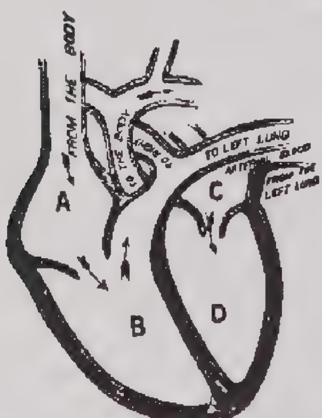

FIG. 123.—COURSE OF THE CIRCULATION THROUGH THE HEART.

307. The pulmonic circulation, like the various stages of digestion and absorption, is a preparatory process. It is the culmination of the two processes which began with eating and breathing. It is the final stage in the complete adaptation of food and air to the support and nourishment of the living tissues. The processes which follow are connected with the placing of the prepared materials, and later with the removal of worn-out parts and broken-down cells.

308. The Systemic Circulation.—What is the name of the largest artery? Where is its beginning?

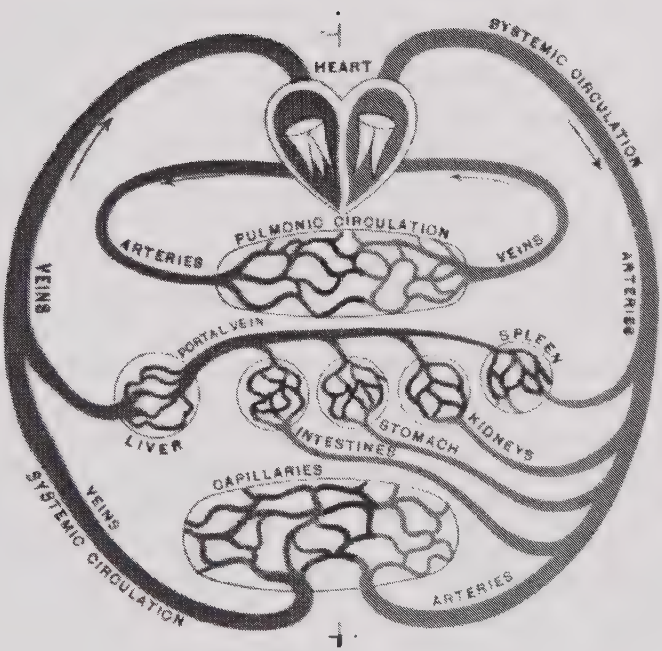

FIG. 124—DIAGRAM OF THE CIRCULATORY SYSTEMS.

At what rate does the blood move in the aorta? What kind of blood is it? It is called *arterial* blood, while the blood carried by the veins is called *venous* blood.

This arterial blood coming from the left ventricle of the heart passes into and through the aorta and its branches to all parts of the body. As the aorta leaves the heart it rises upward towards the neck, then arches over and proceeds downward in front of the spinal column. In its course it gives off several large branches. Two of these branches called the *carotid* arteries pass upward, one on each side of the neck, to the head; two others called the *subclavian* arteries go one to each arm; as the aorta passes downward it gives off a large branch, the *cœliac* artery, from which smaller branches go to the stomach, liver, and spleen. The aorta then gives off two branches, the *renal* arteries, one of which goes to each kidney; then the *mesenteric* arteries to the intestines, and at last it is itself divided into branches called the *common iliac* arteries. These, subdividing, supply the pelvis and the lower limbs. As a general rule it may be said that the arteries are straight, thus taking the shortest course to the tissues which they supply. It is a also general rule that the farther an artery is away from the heart the smaller its caliber becomes.

309. The arteries in their courses divide and subdivide, becoming smaller and smaller, and carrying the life blood into every part of the body. Finally they terminate in the tissues in a very close network of exceedingly small and delicate blood vessels which are called *capillaries*. These vessels are so small that they are invisible to the naked eye, and so closely do they

lie to one another in many of the tissues that it is impossible to insert the point of a needle without penetrating one or more of them. The capillaries vary in size from 1-25000 to 1-2500 of an inch in diameter. Their walls consist of but a single layer of very thin, delicate membrane. They exist in every tissue of the body except the cartilages, the nails, and the hair. These tissues do not receive any blood supply, but are nourished by nutriment absorbed from other tissues.

One of the earliest and most persistent effects of alcohol is the distention of the walls of the capillaries in many parts of the body. This is not only apparent in the flushed and florid faces of those who indulge in alcoholic liquors, but its effects upon the circulation and upon the health of many of the tissues are highly injurious.

310. It is while circulating through the capillaries that the blood performs its mysterious functions so necessary to the maintenance of life. It supplies to each tissue the particular nourishment which it requires; it removes broken-down cells and replaces them with new ones; it carries away from the tissues the worn-out matter and waste particles which are of no further use in the processes of life.

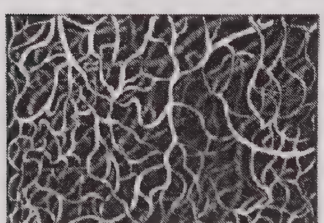

FIG. 125.—PLEXUS OF SMALL BLOOD VESSELS.

311. Not only are the ordinary and normal processes of restoring and building thus constantly carried on, but there appears to be always a reserve force in readiness for the repairing of tissues accidentally injured. If there is a

broken bone, the tiny blood vessels immediately set to work to repair the fracture by depositing bony material and building up a bony structure to reunite the separated parts. If a muscle has been cut, the capillaries proceed to fill up the wound by depositing the necessary muscular or connective tissue in such manner as to knit the parts together again. Just how this is done, we cannot tell; but we know that it is done, and that no mistake is made in the selection of the proper building and nutritive materials from the blood.

312. Assimilation. — The process by which the nutritious elements of the blood are thus separated from it and become parts of living tissues is called *assimilation*. Perfect assimilation depends much upon the purity of the blood which circulates in the arterial capillaries. The health and strength of the whole body depends upon this. If the food which has been eaten is not healthful, or if any poisonous substance, as alcoholic liquor, has gained access to the circulatory vessels, or if the process of blood purification has been imperfectly performed in the lungs, then assimilation cannot be accomplished satisfactorily, and discomfort and disease will result.

313. While the blood is doing its mysterious work in the capillaries it never stops, but flows on in the same steady current as before. It loses a part of its oxygen (§ 306) and other nutritive elements, and becomes loaded with the débris of the wearing-out tissues. It assumes the color which is characteristic of venous blood (§ 285). It becomes unfit to perform any further useful function in the tissues. It issues from the capillaries, flowing onward into the minute veins into which they merge.

314. The small veins, like the capillaries and small arteries, form a complicated and delicate network of tubes which spreads through the tissues in every direction. These minute tubes unite with one another to form larger ones, and the larger ones unite to form still larger, while their course is all the time directed towards the heart. Finally the various streams of venous blood, full of the débris of broken-down cells and charged with poisonous and useless matter, unite in two strong-flowing currents, the venæ cavæ, and are poured, as we have already seen, into the right auricle of the heart. Since leaving the heart, by way of the aorta, the blood has made the circuit of the system; hence we call its passage through the arteries, the capillaries, and the veins the *systemic or greater circulation.* (See Fig. 124.)

315. Review.—Trace one complete circulation of a definite quantity of blood, beginning at the right auricle and ending at the same place. Name and describe each set of vessels through which it flows.

Name in their order the valves or orifices through which it passes. Describe the two great changes which it undergoes.

What is the average length of time required for one complete circulation? How may the rapidity of the circulation be increased? Tell one way in which its rapidity may be diminished.

In what class or classes of persons is the rapidity of the circulation greatest?

From what you have learned about the effects of alcohol, give reasons why the wounds of a person addicted to its use are always slow to heal.

316. The Temperature of the Blood.—During its cir-

culation the temperature of the blood varies somewhat in the different channels through which it passes. In the blood vessels which are situated deeply within the body, it may be as high as 107° F.; in those quite near to the surface, the temperature is much lower. Its average temperature is about 98.5° F.

Experiments.— Place the bulb of a thermometer under your tongue. Let it remain for two minutes, then notice the temperature recorded. This shows about the average temperature of the blood.

Place the bulb of the thermometer close up under the arm. Let it remain for some time, and then notice the temperature recorded.

317. Secretions Derived from the Blood.—The various and complex functions which the blood performs during its circulation have been only partially indicated in the foregoing brief description of its course. The numerous glands, as it flows, remove from it the elements composing the particular substance which they are designed to produce or secrete. From it the salivary glands derive their saliva, the mucous glands their mucus, the gastric glands their gastric juice, the pancreas its pancreatic fluid, the liver its bile.

318. The Portal Circulation. — In its circulation through the liver the blood undergoes certain changes and probably performs certain functions which are but imperfectly understood. The venous blood which has circulated through the principal digestive organs is received into a large vein called the portal vein, and by it is conducted into the liver (Fig. 126). There the portal vein divides and subdivides into innumerable branches, forming an interlacing network of minute vessels throughout the organ. The hepatic artery, a branch

of one division of the aorta, also penetrates the liver, sending its branches to all parts of its lobes and lobules. In the capillaries of the liver the blood of the portal vein is mingled with the blood of the hepatic artery; this mingled blood is then collected by small veins which, uniting and reuniting, finally form the large trunk called the *hepatic vein.* By the hepatic vein the blood which has thus performed the circuit of the liver is conveyed directly to the ascending vena cava, whence it soon reaches the heart.

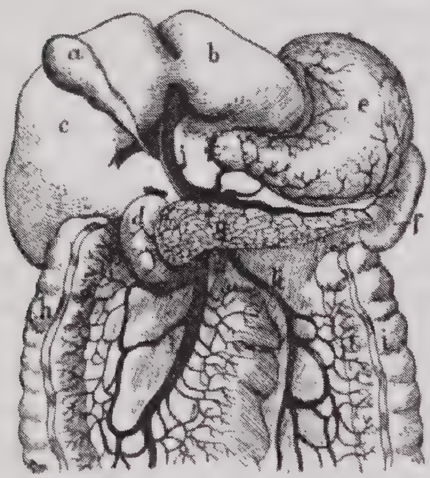

FIG. 126.—THE PORTAL VEIN.
j, k, l.—The portal vein and its branches.
b, c.—Lobes of the liver. g.—The pancreas.
a.—Gall bladder. d.—The duodenum.
e.—Stomach. f.—The spleen.
h, i.—The colon.

This peculiar course of the blood through the liver is called the *portal circulation.* It is, however, by no means a distinct circulation, like the pulmonic, but only one stage of a part of the great systemic circulation. (See Fig. 124.) During its passage through the portal circulation, important changes take place in the blood and certain new substances are produced in the tissues of the liver. The blood loses a portion of its elements, and not only is bile secreted but a kind of animal sugar is formed in the substance of the liver. These, with other changes, appear to be necessary to

the maintenance of health, and when disorders of the liver prevent their perfect performance, the entire system suffers.

319. Excretions from the Blood.—As the blood circulates it not only supplies the glands with the materials which compose their various secretions, but it delivers to the excretory organs such matters as are of no value to the system and must be expelled from it. A very large portion of this waste is carried to the lungs and by them expelled during the process of breathing; but no inconsiderable part is excreted through the medium of the kidneys and of the glands of the skin. Of these various processes more will be said in a later chapter (§ 358).

320. Practical Review.—What is generally understood by the circulatory system? In what respects does the systemic circulation differ from the pulmonic? Of which of these is the portal circulation a branch?

Explain how exercise taken regularly and moderately may strengthen the heart's action and improve one's general health.

Explain how alcohol, by causing a shrinkage of the red blood corpuscles, may retard the proper nutrition of the tissues.

Explain how palpitation of the heart may frequently be produced by the use of alcoholic drinks (§ 281).

Explain how, through the same cause, the walls of certain of the veins and arteries are made to become thinner and weaker, and sometimes so frail as to burst from the pressure of the blood within. (When this occurs in the brain, as is frequently the case, death is the immediate result, and the person is said to have died of apoplexy. Frequently persons who do not use

alcohol die of apoplexy.) Why is apoplexy more common among drinkers than among total abstainers?

Why are drinkers of alcoholic liquors less able to survive surgical operations than those who abstain from their use? Give one reason why drinkers are more liable to contract disease.

Tobacco contains a poisonous substance called nicotine. In what way does this poison affect the heart (§ 282)? Why does the smoking of cigarettes hinder the proper development of the body? Why are boys who acquire the habit not likely to become well-formed, strong, and handsome men?

XXXII.—THE LYMPH-VASCULAR SYSTEM.

321. The lymph-vascular system is closely connected with the blood-vascular system, and in its functions is tributary to it. The *lymphatics*, or lymphatic vessels, are tubes somewhat resembling in structure the veins of the blood-vascular system. They are found in nearly all parts of the body. The mode of their origin has not been determined with absolute certainty, but it is generally agreed that they commence in the skin, by what is known as a *capillary plexus*, which is separate from the blood capillaries. A lymphatic plexus is a delicate and close network of minute lymphatic vessels. Besides the plexus of origin, a second plexus, composed of larger vessels, is situated just beneath the skin. Just beneath the surface of the mucous membrane is also a plexus of similar appearance and structure. The lymphatics originat-

ing in and composing these plexuses may be classed as *superficial* lymphatics. Lying deeper in the tissues are other lymphatics, much larger than the superficial. These receive lymph from the superficial lymphatics and accompany some of the deeper veins in their course. They contain many valves, so closely set as to give the vessels a peculiar beaded appearance, especially when they are distended with lymph. The small superficial lymphatics have no valves.

FIG. 127.
A.—Part of a lymphatic vessel laid open, with three pairs of valves.
B. — Longitudinal section of a lymphatic vessel, showing the valves closed.

A peculiarity of the lymphatic vessels is that they continue of about the same size throughout their length. They are much smaller than the veins, rarely being more than one sixth of an inch in diameter. As they pass onward toward the great duct by which they communicate with the blood-vascular system they frequently anastomose with each other, that is, each gives off branches which communicate directly with others.

322. As the lymphatic vessels proceed in their course, they pass through numerous rounded, glandular masses, called *lymphatic glands*, which vary in size from that of a pea to that of an almond. Each gland, besides being filled by a network of small lymphatics, is also permeated by numerous capillary blood vessels. The functions of these glands are not fully understood, but it is supposed that they in some manner affect or produce the corpuscular elements of the lymph. This

supposition is supported by the fact that, in the vessels which have not passed through any of these glands, the lymph contains but few corpuscles, while in the large trunks which carry lymph that has passed through several such glands the corpuscles are very numerous.

FIG. 128.—LYMPHATIC VESSELS OF THE HEAD AND NECK.

323. Lymph. — But what is the lymph? It is the fluid which is carried by the lymphatic vessels. In its composition it is very similar to the blood; indeed, it contains all the component parts of the blood except the red corpuscles. These parts, however, do not exist in the same proportions as in the blood.

FIG. 129.—LYMPHATIC GLAND.
A.—Gland. B, B.—Lymphatics.

Lymph consists of colorless corpuscles, of plasma somewhat diluted with water, and of a very small proportion of solid matter; and, like the blood, it has the

power of coagulation. It is of a light yellowish color, and has an alkaline reaction.

324. "The whole plan of lymphatic vessels and lymphatic glands is a system of drainage similar to

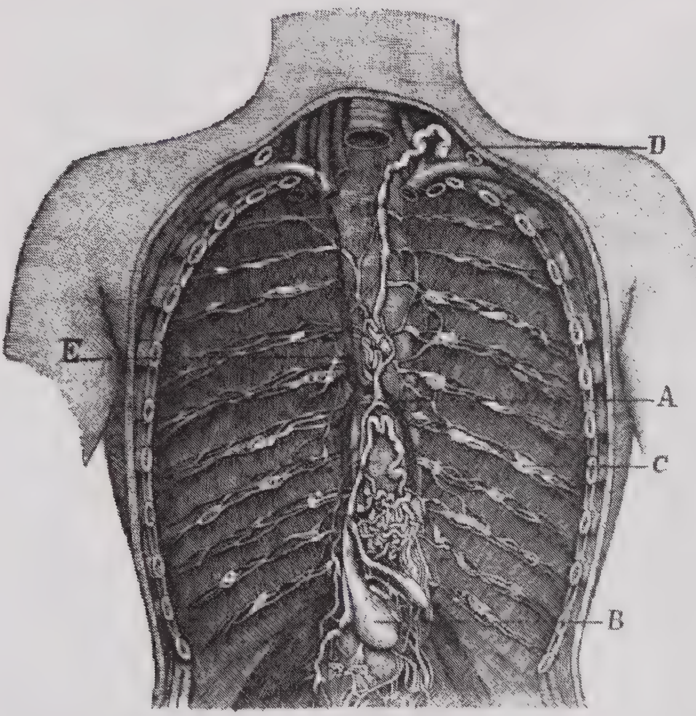

FIG. 130.

A.—The thoracic duct. B.—The receptaculum chyli.
C.—Lymphatic gland. D.—Point where the thoracic duct empties into the venous system.
E.—Large vein.

that employed in some soils, in which the water drained from boggy lands forms channels, which unite to form larger streams, still increasing in size, and occasionally expanding into pools, where fresh supplies of materials are absorbed, and at last pouring into a river or the open sea."

The lymphatics from the right side of the head and the right arm and shoulder pour their contents directly into the blood-vascular system at the junction of the right jugular vein with the right subclavian vein. The lymph from all the rest of the body, as well as that part of the chyle which has been taken up by the lacteals (§ 260), passes through the thoracic duct, and from it is emptied into the blood-vascular system at the junction of the left subclavian vein with the left jugular vein. It is at these two points, therefore, that the lymph-vascular system connects directly with the blood-vascular system.

Fig. 131.—Superficial Lymphatic Vessels of the Arm.

325. The quantity of lymph discharged daily into the blood-vascular system has been variously estimated, and is doubtless greatly modified by different circumstances and conditions. The average amount in a strong man is thought to be somewhat less than one twentieth of the entire weight of his body. The lymph not only has its ending in the blood, but, like the other fluids of the body, it is doubtless produced from the blood. Its pas-

sage through its own vessels, from the time of its origin in the blood until it is again mingled with that liquid, is called the *lymph-vascular* or *lymphatic circulation*. As an auxiliary to the systemic circulation it performs an important part in the process of nutrition.

326. The Spleen. — Lying within the abdominal cavity at the left side of the stomach is a peculiar gland called the *spleen*. It is about the size of the palm of the hand, flat and oval, and is of a purplish or deep red color. Its functions are not well understood, but it is supposed to be an adjunct of the vascular system and to promote in a mysterious way the formation of white blood corpuscles. Instances are known, however, of its having been removed entire from animals without apparent injury to their general health.

327. Review.—Of what does the vascular system consist? In what respects does the blood-vascular system differ from the lymph-vascular system?

Which of the lymphatics sometimes carry another substance besides the lymph? Between what two systems are these lymphatics a connecting link? What are they sometimes called? Why?

Of what system is the thoracic duct a part?

At what point in the circulatory system is the nutritious food finally converted into blood?

Of what use is the blood? Why does a loss of blood diminish one's strength?

Why do the nose and face of a person addicted to the use of alcohol assume a purplish hue?

Why are drinkers of alcohol more liable than others to be afflicted with heart disease?

What is the best rule to observe with reference to both alcohol and tobacco?

XXXIII.—THE LUNGS AND AIR PASSAGES.

328. After the blood is expelled from the right auricle of the heart, to what organs is it carried? By what vessels is it returned to the heart? What is this

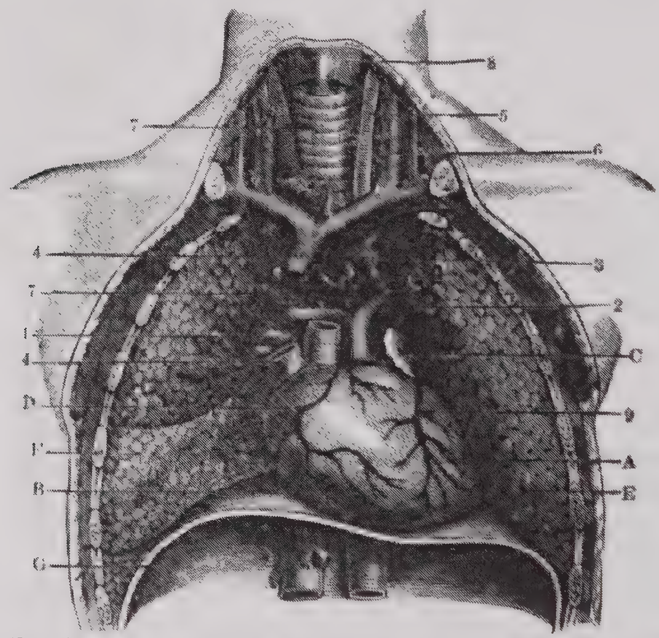

FIG. 182.—THE POSITION OF THE LUNGS AND HEART IN THE CHEST.

A. B, C. D.—Heart. 2.—Pulmonary artery. 6.—Jugular vein.
E, F.—Lungs. 3.—Aorta. 7.—Trachea.
G.—Diaphragm. 4.—Superior vena cava. 8—Larynx.
1.—Pulmonary vein. 5.—Carotid artery. 9.—Coronary artery.

part of the circulation of the blood called? Let us now learn something more concerning this life process which is constantly going on in our bodies.

329. The Lungs.—The lungs, in which the purification of the blood is chiefly performed, are two conically shaped organs situated within the chest, one on each side. Together with the heart, which is between them, they completely fill the thoracic cavity. Each lung is covered over the greater part of its surface by a smooth serous membrane, which, being reflected outward at the root of the lung, forms also the interior lining of the walls of the chest. This membrane, which is called the *pleura*, is very smooth and is kept always moist by a *serous fluid*, which it secretes in an exactly sufficient quantity to prevent the friction which would otherwise be caused by the movements of the lungs during the process of breathing. The bases of the lungs lie along the upper surface of the diaphragm. Their apexes are at the top of the chest and project towards the bottom part of the neck. Their color is a pinkish gray marked with numerous irregular spots and streaks of a dark hue. The right lung is divided by means of fissures into three lobes; the left into two lobes.

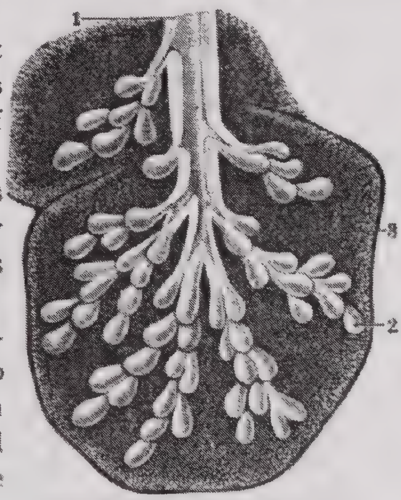

FIG. 133.—A LOBULE OF A LUNG.
1.—Small bronchial tube.
2.—Air-cell.
3.—Lung tissue.

330. The Structure of the Lungs is very peculiar. They are composed of a delicate elastic tissue in which are situated innumerable minute cavities called *pulmonary lobules*, each of which is a collection of more

minute cavities called *air vesicles*, or air cells. The walls of the air vesicles are extremely thin, being made up, for the most part, of a fine, close network of capillary blood vessels. These walls are very elastic and are capable of great distention. The vesicles, although so minute, are so numerous that the combined surfaces of their walls present a wonderfully large area—equal, it is estimated, to 1,400 square feet. Each vesicle is of a conical form and the lobule or collection of vesicles opens at its apex, not into another vesicle or lobule, but into a minute air passage called a *bronchial tube*.

FIG. 134. — SECTION OF A LOBULE.
a. Interior of lobule.
b.—Bronchial tube.
c, c, c. — Air vesicles.

331. The Bronchi.—The walls of the smaller bronchial tubes are composed of a delicate fibro-elastic membrane, and each of the lobules of the lungs may be said to consist of one of these tubes with its connecting vesicles. The different bronchial tubes, like the tributaries of a river, unite and form larger tubes, and these finally combine into still larger passages, called *bronchi*, one of which extends from the interior of each lung towards the upper part of the chest. There the two open into and form a single passage, called the *trachea*, or *windpipe*.

332. The Trachea is a tube about four and one half inches long and three fourths of an inch in diameter. It extends from the middle of the upper part of the chest upward to the anterior part of the neck. The walls of both the trachea and the bronchi are lined with mucous membrane. They are composed chiefly

of fibrous tissue and encircling rings of cartilage which preserve their rigidity and prevent them from collapsing during the acts of breathing. The trachea is encircled by eighteen of these rings.

333. The Larynx.—The upper end of the trachea

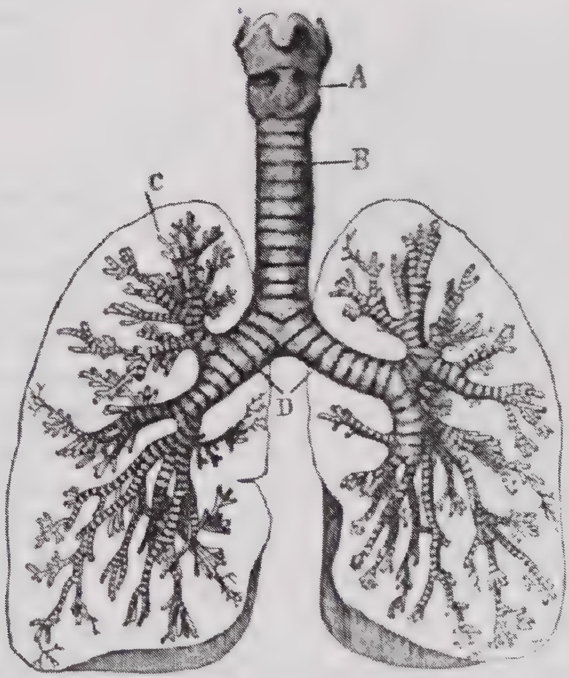

FIG. 135.—THE AIR PASSAGES.
A.—The larynx. D.—The bronchi.
B.—The trachea. C.—Small bronchial tubes.

opens into and is continued in a box-shaped cavity, called the *larynx*, the walls of which are likewise composed chiefly of cartilage, and are therefore rigid and to a certain extent unyielding. The larynx is lined with a delicate mucous membrane, and in it are situ-

ated certain peculiar ligamentous bands which are concerned in the production of the voice and are called *vocal cords*. Of the structure of these cords and of their peculiar function more will be said in the proper connection (§ 355).

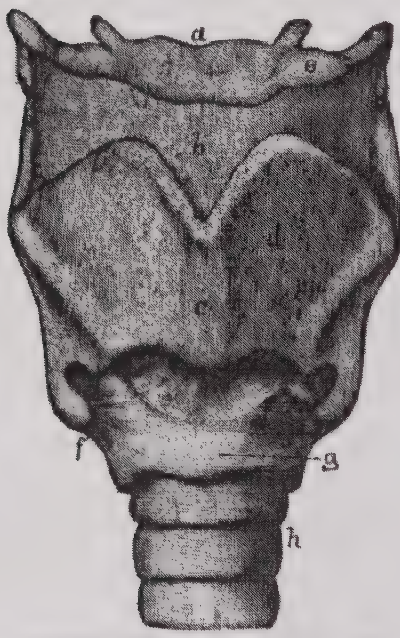

FIG. 136.—ANTERIOR SURFACE OF THE LARYNX.

a, e.—Hyoid bone. b.—Membrane.
c, d.—Thyroid cartilage (Adam's Apple).
f.—Ligaments. g.—Cricoid cartilage.
h.—Trachea.

What is the pharynx? Where is it situated? How many and what passages open into it or from it?

The larynx is immediately below the pharynx, with which it communicates through an opening called the *glottis*, which is the space between the vocal cords. Attached to the anterior part of the glottis is the small leaf-shaped plate of cartilage known as the *epiglottis*.

334. A Short Review.—Describe the epiglottis and its function (§ 213).

Which one of the passages into the pharynx from above is the natural entrance and exit for the air during the process of breathing?

Through which other passage may the air be taken in or expelled?

Draw a deep breath, filling the lungs with air. Now

expel the air slowly. Notice the motion of the ribs when you are taking in the air and also when you are expelling it.

What are the muscles called which elevate the ribs when the breath is drawn in (§ 94)? Are these muscles of the voluntary, or of the involuntary type?

XXXIV.—RESPIRATION.

335. Definitions.—The process of breathing is called *respiration*. The passages and organs concerned in the process of breathing are called *respiratory organs;* and when considered together as an assemblage of organs designed to accomplish a particular object, they constitute what is known as the *respiratory system.*

The word respiration, however, has sometimes a much broader signification, being used to indicate the combining of oxygen with the blood and the removal of carbonic acid and other impurities from it.

The act of drawing the air into the lungs is called *inspiration*. The reverse act of expelling the air from the lungs is called *expiration.*

Name in their order the passages or organs through which a given portion of air passes on its way from the pharynx to the lungs. Now write the names of the respiratory organs in their proper order.

336. How We Take Breath.—The thorax, or chest, is an air-tight compartment, or box, the interior of which has no communication with the outer air except through the air passages. Within it are the lungs and the heart, which fill it almost completely. Describe

the framework of its walls (§ 47). Describe the muscular partition that separates it from the abdominal cavity (§ 94).

When the diaphragm is relaxed it extends upward in a vaulted form into the thoracic cavity, assuming a shape somewhat like that of an inverted wash basin. When it contracts it assumes a more horizontal shape and thereby increases the capacity of the chest. When the intercostal muscles which control the motions of the ribs are relaxed, the walls of the chest are quiescent and considerably reduced in circumference. But when they contract, the lowermost ribs are elevated and their points are separated, thus increasing the size of the chest.

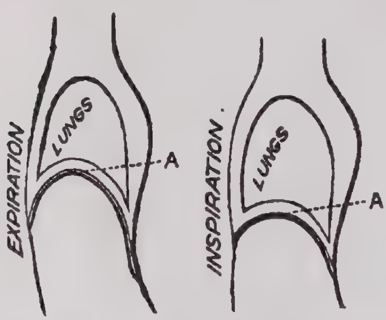

FIG. 137.— DIAGRAM SHOWING THE MOVEMENT OF THE DIAPHRAGM DURING THE ACT OF BREATHING.
A, A. Diaphragm.

Experiment. — With a tape line measure the circumference of the lower part of your chest when all the muscles are relaxed and at rest. Then, by contracting the diaphragm and intercostal muscles, expand the chest to its fullest extent and again measure its circumference.

What took place in your lungs when you expanded your chest? Why?

337. The lungs, being very elastic and largely composed of air cells, readily adapt themselves to the changes in the capacity of the chest. Hence, together with the enclosing diaphragm and chest walls, they act in nearly the same manner as a bellows. Enlarge the

capacity of the bellows by separating its bounding walls, and the air rushes in and fills it. Depress the sides of the bellows so as to diminish its capacity, and the air is forced out through the nozzle. It is so in breathing. Any expansion of the chest produced by the contraction of the respiratory muscles, is accompanied by a like expansion of the lungs, and at the same time the air rushes into them and prevents a vacuum. Any contraction of the chest produced by the relaxation of the respiratory muscles, diminishes the volume of the lungs, and the air in them is accordingly forced out through the same passages by which it entered. It is evident from what has been said, that inspiration is an *active* operation, while expiration is ordinarily a *passive* one. The former is the result of muscular contraction, the latter of muscular relaxation.

338. Thought and Experiment.—To what extent may a person control his breathing?

How often do you ordinarily breathe in a minute? Count and see. When do you breathe most rapidly?

How is the frequency of breathing influenced by any kind of active exercise? What class of persons breathe the most rapidly?

339. Some Facts about the Air.—To understand why pure air is so necessary to health and comfort, and even to life itself, it is necessary to know something about its nature and composition as it exists in the atmosphere that surrounds us. Air is a mixture of two gases, oxygen and nitrogen. The oxygen is the element necessary to all animal life; the nitrogen is useful only as a diluent. In pure air there are about four parts of nitrogen, by weight, to one part of oxygen; that is, each ounce of oxygen is diluted with four ounces of

nitrogen. Since the respiratory organs are adapted to the breathing of oxygen thus diluted, a stronger mixture of that gas might produce harmful results. The air at most times contains small quantities of other substances, such as carbonic acid, watery vapor, and various impurities. In closed rooms and other localities where the free circulation of air is impeded, the proportion of impurities is largely increased (see § 537).

340. Oxygen is the most important of the supporters of life, for without it existence cannot continue even for a brief period. Like the food, it aids in sustaining and nourishing the tissues. It has also other uses. It has great affinity for many substances, and its union with them is accompanied by the production of heat. In the capillaries it unites with the carbon which is produced from the broken-down cells, thus forming carbonic acid, a gas that is easily expelled from the system. Oxygen is the most active supporter of combustion, and is as necessary to the production of fire as to the maintenance of life. No other substance seems so necessary to all the important processes of nature as this colorless, invisible gas.

Through the medium of what system of organs does the food obtain access to the blood-vascular system? Through the medium of what system does oxygen obtain access to the blood-vascular system?

341. Nitrogen is a negative element, just as oxygen is an active and positive one. It does not support life; it does not aid in combustion; its principal purpose in the air seems simply to restrain its impetuous fellow gas, oxygen.

342. An Inspiration.—Let us now follow a given

portion of air into the lungs. For convenience in description let us call this given portion AIR.

Take a good breath. This is what we call an inspi-

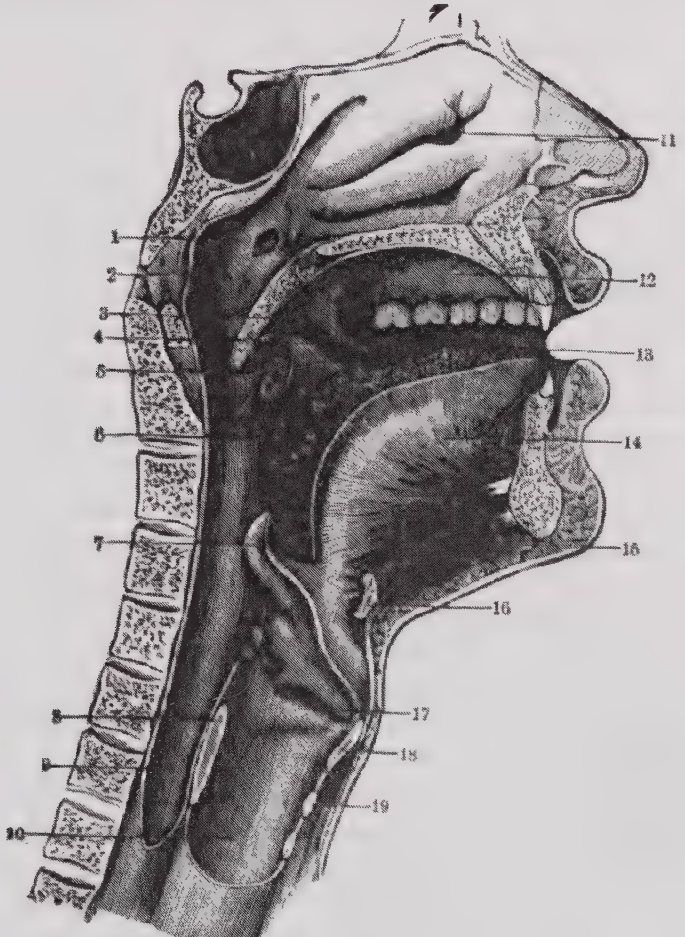

FIG. 138.—SECTIONAL VIEW OF THE UPPER AIR PASSAGES.

1, 2.—Back of nasal passage.
3, 4.—Back of mouth.
5.—Tonsil.
6.—Pharynx.
7.—Epiglottis.
8.—Cartilage of larynx.
9.—Esophagus.
10.—Trachea.
11.—Nose.
12, 13.—Mouth.
14.—Tongue.
15.—Hyoid bone.
16.—Larynx.
17, 18.—Cartilages.

ration. Observe as the chest is expanded how AIR rushes through the air cavities of the nose. During its passage through these cavities it becomes slightly warmed, thus adapting its temperature to that of the delicate organs which it is about to enter. Passing through the pharynx, it is admitted by the epiglottis into the cartilaginous chamber called the larynx.

The epiglottis is a faithful guardian of the air passages, admitting only the gaseous air and carefully excluding all solid or liquid substances. If, by any accident, some such substance should slip past it into the larynx, the delicate nerves in the walls of the latter give the alarm, and violent fits of coughing ensue in the effort to expel the intruder. For coughing is but a quick and spasmodic expulsion of air from the lungs and air passages, generally for the purpose of keeping them clear of all obstructions.

But let us suppose that, this time, no such obstruction has interfered with the breathing. The AIR passes onward into the trachea, or windpipe, which is always kept distended by its eighteen cartilaginous rings. The two bronchi are simply branches of the windpipe, one extending to the right lung, the other to the left, and their structure is identical with it. The mucous membrane of both the trachea and its branches is lined with epithelium of that peculiar variety called *ciliated epithelium* This epithelium is full of delicate, hair-like processes which have a continual wavy motion, producing a kind of current the direction of which is always upwards, or from within outwards. This pecu-

FIG. 139.—CILIATED EPITHELIUM LINING THE BRONCHIAL TUBES.

liar current helps in the removal of excessive secretions, such as mucus, and of foreign substances, such as dust, that may have intruded into these passages.

The AIR, rushing through the bronchi and smaller bronchial tubes, finally enters the air vesicles, or cells, which, being extremely elastic, are expanded in proportion to the expansion of the chest cavity, and are as quickly filled with the indrawn air. The expansion of the air cells is, of course, simultaneous with the distention of the lungs as a whole

343. The lungs are now filled with AIR. How much air do you suppose they can contain? The average extreme capacity of these organs, that is, the total quantity of air which they are capable of containing, is estimated to be 330 cubic inches. In other words, we may say that all the air vesicles in each lung, taken together, are capable of holding as much as a box six inches long, five and one half inches wide and five inches deep. Of the whole amount of air in the lungs, 200 cubic inches remain in the vesicles during all ordinary acts of breathing; one half of this cannot be expelled, except by forcible expiration; and the other half cannot be expelled at all. With each ordinary inspiration, about twenty cubic inches is taken into the lungs, and with each ordinary expiration about the same amount is expelled. By a forced expiration, however, about 110 cubic inches of air may be expelled from the lungs.

344. What Takes Place in the Air Cells.—The air cells being inflated with pure AIR, a wonderful transformation instantly occurs. By endosmosis a part of the oxygen in the AIR passes through the thin walls of the air cells and enters the minute blood vessels which everywhere traverse them. The oxygen combines at

once with the elements already present in the blood that fills these vessels, causing the red corpuscles to assume a brighter color, and imparting new life to the vital fluid. The reinvigorated blood, as we have already learned, is then hurried onward to the heart and thence into the systemic circulation.

At the same moment that the life-giving oxygen is thus absorbed into the blood, another wonderful process, exactly the opposite of the first, is taking place. The various impurities—the watery vapor, the useless débris of wearing-out tissues, especially carbonic acid gas—which were carried to the heart by the veins and are now brought to the lungs by the pulmonic arteries, are, by *exosmosis*, passed out through the delicate walls of the minute blood vessels and air cells, to become mixed with the AIR which has just parted with a portion of its oxygen. These are two great changes which are taking place in the lungs with every breath of air that is taken. Upon these changes life depends.

345. Interesting Facts.—We have now followed a definite portion of air, AIR, through all its changes of place and composition to the completion of a single act of inspiration. The time occupied has been but a few seconds, although we have consumed several minutes in describing it. Here are some interesting facts that are worth remembering:

It is estimated that the amount of oxygen absorbed by the blood is equal to about one twentieth of the volume of air that is inspired. What portion of its oxygen, therefore, does the air lose in the lungs?

In the course of a day about fifteen cubic feet of oxygen is taken into the blood and consumed by one

person. To supply this amount of oxygen, how many cubic feet of air must be inhaled?

More oxygen is consumed while laboring or exercising and during the period of digestion, than while the body, with all its organs, is at rest. As a consequence what is the effect at such times upon the breathing; upon the circulation of the blood? Explain why this is so.

346. An Expiration. — Let us suppose that the definite portion of air which we have called AIR is still in the vesicles of the lungs. It has been deprived of one fifth of its oxygen, and it has acquired instead a miscellaneous mixture of carbonic acid, watery vapor, and other impurities. For convenience we may now call it EXP. AIR. When it was first drawn from the atmosphere we know it was pure air, and it might have been described in this way:

AIR = 23 parts of oxygen + 77 parts of nitrogen.

It may now be described as follows:

EXP. AIR = 18 parts of oxygen + 77 parts of nitrogen + 5 parts of impurities.

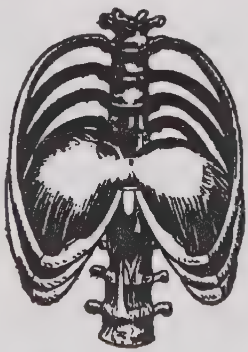

FIG. 140.—THE DIAPHRAGM.
The upper ribs removed.

This impure air cannot long remain in the lungs; indeed, nature requires its immediate expulsion. The muscles of respiration, therefore, are entirely relaxed. The diaphragm reassumes its vaulted shape, rising upward in the thoracic cavity, while at the same time the ribs drop to their position of rest. The capacity of the chest being thus diminished, EXP.

AIR, with its load of impurities, is forced from the lungs and escapes by the same passages through which it, as AIR, entered. This constitutes a single *expiration.*

347. The amount of carbonic acid gas removed from the body by expiration varies under different circumstances, but the approximate average is about fifteen cubic feet per day. Age, diet, sex, digestion, and exercise, all have a marked influence upon the amount and quality of the impurities expired at every breath. If inspired air be impure it is for obvious reasons incapable of imparting the necessary amount of oxygen to the blood in the lungs. Being already loaded with impurities, it is also unable to carry away the waste matters with which the blood is ready to part.

The acts of respiration are only partially under the control of the will. They are regulated and governed by the nervous system—a distinct nervous center, as we shall presently learn, existing for this sole purpose (§ 390).

348. Asphyxia.—Arterial blood is capable of circulating freely in the capillary blood vessels; venous blood, loaded with carbonic acid gas, is in such a condition that it cannot circulate in them. When the supply of oxygen is shut off from the lungs, and the blood fails to be purified, a condition called *asphyxia*, or *suffocation*, results. In asphyxia the blood becomes completely saturated with carbonic acid gas. This gas having no means of escaping from the body, circulation in the capillaries is impeded by it and ceases, the blood fails to return to the heart, and that organ soon refuses to act.

Asphyxia may occur from many causes, drowning, choking, inhalation of poisonous gases, or any serious obstructions in the air passages.

In cases of asphyxia, especially from drowning, life may often be restored, provided the heart has not entirely ceased beating. This is done by supplying the person with fresh air, so that oxygen may be imparted to the blood, and the carbonic acid removed. The air must be made to enter the lungs, and the only way this can be done is by performing artificial respiration, a procedure with which every one should be familiar (§ 565).

349. Injuries to the Lungs.—The lungs and, in fact, all the organs of the respiratory system are liable to diseases more or less serious. These are usually the result of exposure, or of carelessness, or of some species of excess. To preserve the respiratory organs in a healthy condition great care should be taken that they do not become injured by the inhalation of foul or impure air, or of noxious and irritating gases. The proper ventilation of sitting rooms and sleeping rooms should receive special attention (see Chapter LVIII).. Sudden exposure to heat or cold often affects the respiratory organs. A severe cold is a matter of no small consequence, for it may be the beginning of a serious, if not fatal, disease of the respiratory organs.

350. How Alcohol Affects the Respiratory Organs.—When alcohol is taken into the stomach it requires but a few moments for a portion of it to reach the lungs. Through what channels does it pass before entering these organs? Trace the course of a quantity of liquor from its entrance into the stomach to its entrance into the air vesicles of the lungs. What are some of its effects upon the blood vessels through which it passes? What are some of its effects upon the heart? Through what vessels is it carried from

the heart to the lungs? What effect does it have upon the blood with which it is mixed? Does it exist in the blood as an impurity? How do impurities escape from the blood while it is passing through the lungs (§ 344)? Suppose the blood is overloaded with impurities, can all escape in this way? What becomes of that portion of impurities which cannot escape? If they are carried again into the general circulation will they have an injurious effect upon the tissues? Explain how it is that a drinker's breath is sure to betray him.

351. A considerable proportion of the alcohol which a drinker takes into his stomach is soon expelled from the system through the lungs. For some time after the drink has been taken, the air of each expiration is loaded with the fumes of this poison. In this way the lungs act as a kind of safety valve; for if they did not thus expel much of the poison from the system its effects would be far more rapid and deadly than they are. But while in some measure protecting the other organs from this destroyer, the lungs and air passages themselves suffer great injury by contact with it. The delicate tissue which composes the walls of the air vesicles becomes inflamed, and the vesicles themselves are incapable of becoming fully distended by the air. The lungs gradually assume a deep red or brownish color. The walls of the bronchi become affected, and chronic bronchitis is frequently the result. These affections of the air passages, as a matter of course, interfere with the circulation of the blood and hinder its proper and prompt purification in the lungs; consequently the nutrition of the whole system is impaired and all the life processes are more or less impeded and impaired.

Frequently the drinker of alcoholic liquors is troubled with catarrhal inflammation of the throat. The voice becomes hoarse and husky, or, in some cases, fails entirely. The mucous membrane which lines the larynx and other air passages becomes thickened and congested; the small glands which secrete a mucous fluid to keep the membrane moist are unable to perform their proper function, and therefore deposit a thick, viscid substance upon its surface. As a consequence respiration is impeded, and a persistent, hacking cough is produced. Is it any wonder that colds and lung troubles are easily contracted and that they are cured only with much difficulty?

Pneumonia is much more easily contracted by alcohol drinkers than by others; and recovery, if it occurs at all, is more tedious and prolonged.

352. Tobacco Injures the Lungs and Air Passages.—The inhalation of tobacco smoke tends to cause irritation and congestion of the respiratory organs. Many diseases of the mouth and throat are induced or aggravated by the poisonous nicotine which is absorbed by the tissues or brought into direct contact with the delicate and sensitive surface of the mucous membrane which lines the air passages. The throats of many persons are easily irritated by tobacco smoke. This irritation, if continued, causes a redness and soreness of the mucous membrane which lines the larynx and trachea, and frequently results in the disease called "smoker's sore throat." The only cure for this trouble is to give up the use of tobacco altogether. Snuff-taking causes many diseases of the nose.

353. Practical Questions.—In what respect may the respiratory system be regarded as an auxiliary to the

circulatory system? What other system is likewise auxiliary to the circulatory system?

Which is of the greater importance to life, food or air? Why?

At what point does the preparation of nutritive material by the digestive and circulatory systems culminate (§ 344)?

What three systems of organs are concerned in the nutrition of the body? What is meant by nutrition, in the sense intended in the foregoing question?

Which one of these three systems assists only in the building up processes? In what way does each of the others assist in tearing down as well as building up?

If there should be a sudden cessation of both the circulation and the respiration, would the destroying or tearing-down process cease at the same time?

XXXV.—THE VOICE

354 What and where is the larynx (§ 333)? Describe its lining membrane. What is the opening between the larynx and the pharynx called? Describe the epiglottis.

355. Structure of the Larynx. — The cartilages which form the framework of the larynx comprise three single pieces and three pairs. The single pieces are called the thyroid, the cricoid, and the cartilage of the epiglottis. The three pairs are two arytenoids, two cornicula, and two cuneiform cartilages. The cartilages are connected by elastic ligaments or membranes, two of which are the true vocal cords. The prominence on

the front part of the neck, familiarly called the Adam's apple, is formed by the anterior part of the thyroid cartilage.

356. **The Vocal Cords.**—The vocal cords consist of two nearly parallel elastic ligaments running from the angle of the thyroid cartilage to the arytenoid cartilages on the opposite side of the larynx. They are covered with a thin mucous membrane. Above these cords are other ligaments, somewhat similar in appearance, called the superior thyro-arytenoid ligaments, or false vocal cords. The narrow aperture or chink between the true vocal cords is called the *rima glottidis*. By the movements of the arytenoid cartilages, performed by means of the muscles of the larynx, both the size and shape of this opening may be changed; for, when the arytenoids are separated, a corresponding separation of the vocal cords of course occurs and the rima glottidis is expanded into a triangular opening; but when these cartilages are drawn

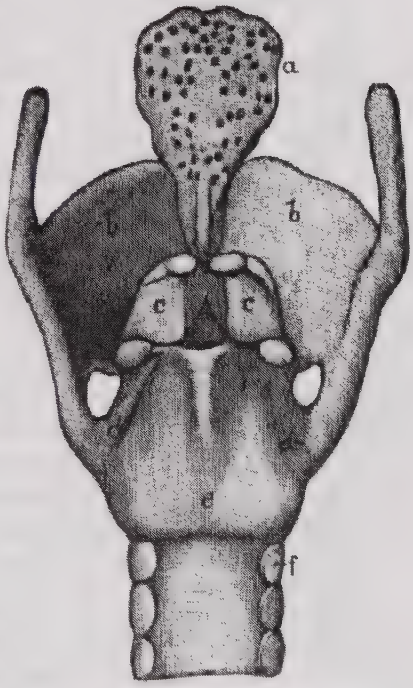

FIG. 141.—POSTERIOR VIEW OF THE LARYNX.

a.—Epiglottis.
b, b.—Thyroid cartilage.
c, c.—Arytenoid cartilage.
e.—Cricoid cartilage.
d, d.—Ligaments.
f.—Upper ring of the trachea.

close together, it is reduced to an oblong and very narrow slit. The movements of the arytenoid cartilages also affect the tension of the vocal cords. It is by the variations in the shape and size of the rima glottidis, together with the changes in the tension of the vocal cords, that the various modifications of the voice are, for the most part, produced. Between the true vocal cords and the false cords are small recesses or pouches of such shape and arrangement as to promote the free vibration of the true vocal cords. The aperture of the glottis is triangular, being wide in front and narrow behind.

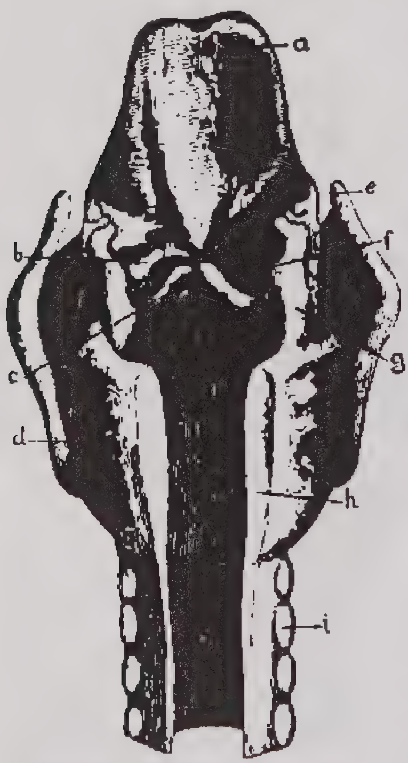

FIG. 142.—INTERIOR OF THE LARYNX, POSTERIOR VIEW.

a.—Epiglottis.
b.—False vocal cords.
c, f.—True vocal cords.
d.—Muscles.
e.—Thyroid cartilage.
g.—Arytenoid cartilage.
h.—Cricoid cartilage.
i.—Trachea.

357. How the Voice is Produced.—Suppose two thin bands of india rubber to be stretched over the end of a large glass tube so as to leave a narrow passage or chink between their free edges. Now, if air is driven forcibly through the tube it will cause the edges of the

bands to vibrate with greater or less rapidity, and a musical note will be produced, the pitch of which will depend upon the number of vibrations within a stated period.

The voice is produced in a similar manner, the trachea being the tube, the vocal cords corresponding to the rubber bands, and the lungs being the bellows that drive the air. If the rima glottidis is wide open the expired air escapes without producing a sound. But when the cords are drawn quite close together and at the same time made somewhat tense by the muscles of the larynx acting with the movable cartilages, then the passage of the air produces a rapid vibration of the free edges of the cords and a vocal sound is the result.

The pitch of this sound depends upon the rapidity of the vibrations; and the rapidity of the vibrations is regulated by the tensity of the cords, the size and shape of the rima glottidis, and the degree of force with which the air is expelled. It is a mistake, however, to suppose that the vocal sounds are directly produced by the vibration of the cords. The vibration of the cords produces an alternate condensation and rarefaction of the column of air which is passing through the larynx; and this latter is the chief cause of the vocal sounds.

The vocal mechanism, therefore, may be compared not to a stringed instrument, as a violin or guitar, but to a reed instrument in which a column of air is thrown into a state of sonorous vibration. The vocal sound is modified by the tongue, teeth, lips, and palate, and thus shaped into articulate words. The quality of the voice may be much improved by systematic cultivation.

XXXVI.—EXCRETIONS AND EXCRETORY ORGANS.

358. What are excretions? In what respect do they differ from secretions? What general name is given to the organs which produce secretions? Give an example of a secretion; of an excretion.

In what respect are the lungs excretory organs? Name two excretions that are discharged through the medium of the lungs.

Excretions are also called *excrementitious substances.* The total amount of excrementitious matter discharged daily from the body approximates on an average the total amount of food consumed. When the excrementitious matter is in excess of the nutrition assimilated, emaciation takes place. When the excrementitious matter is less in amount than the additions derived from nutrition, there is a definite increase in the size and strength of certain of the tissues. In childhood and youth the assimilation is more active and the formation of cells in the different tissues goes on more rapidly than their breaking down or destruction. But how is this in middle age? In old age?

359. The excretory processes are going on at every moment of our existence; otherwise there would at once occur an accumulation of used-up tissue substances in the blood, producing distressing results, which, if not immediately relieved, would end in the stoppage of all life processes. If one of the excretory organs is impaired or is unable to perform the whole of

its functions, the waste matter which should have been removed by it attempts to find some other outlet.

360. Of all the excrementitious matters discharged from the body the most important are the gaseous and watery substances which pass out by way of the lungs. Besides these may be mentioned the sweat and oily secretions of the skin, the excretions from the kidneys, and the cast-off horny scales of the skin, the nails, and the hair.

361. The Skin as an Excretory Organ.—Considered solely in relation to its structure, of what kind of tissues is the skin composed? Considered in relation to its function as an excretory organ, to what class of tissues may it be said to belong? Name two other functions of the skin (§ 138). Describe the general structure of the skin (§ 139). Explain the difference in the color of the skin in different races. What are the papillæ? Describe the sudoriferous, or sweat glands. Describe the sebaceous glands.

FIG. 143.—SURFACE OF THE SKIN.
Showing the ridges and depressions and the openings of the sweat glands.

362. Perspiration.—The sudoriferous or sweat glands are constantly employed in the process of removing waste matters which they derive from the capillary blood vessels in the skin. These waste matters, composing the perspiration or sweat, exist in the glands in a liquid form. Except when the quantity is excessive, they become vaporous as soon as they are

FIG. 144.—A SWEAT GLAND.
A.—Outlet.
B.—The epidermis.
C.—The derma or true skin.

discharged upon the surface of the skin. Perspiration is being produced constantly, but at some times much more freely than at others. The amount depends upon the conditions of heat and moisture, the kind of exercise, the quality of foods and drinks taken, and the general condition of the system. Ordinarily about two pints is excreted from the skin of a healthy person every twenty-four hours.

363. Because of its ready tendency to vaporize, it is difficult to collect sweat for examination in the condition in which it exudes from the sudoriferous glands. It is a clear, colorless fluid having an acid reaction, a peculiar odor, and a slightly saltish taste. Its composition is about as follows:

	Parts in 1,000		Parts in 1,000
Water	995.753	Chloride of Potassium	0.244
Urea	0.043	Phosphates	a trace
Fats	0.014	Albuminates	0.005
Lactates	0.317	Worn out particles of the skin	a trace
Sudorates	1.562		
Common Salt	2.230		

364. In addition to the substances just named as existing in the perspiration, the skin also throws off a small quantity of carbonic acid and watery vapor similar to the discharges from the lungs. If we except the water, the amount of matter excreted by the skin is comparatively small, and yet the importance of its removal is very great. This is shown by the fact that if the entire surface of the skin be covered with

varnish or some other impermeable coating, death will quickly ensue. It is probable that this result is caused by the retention in the system of certain poisonous substances, the exact nature of which is not yet thoroughly understood.

365. The Kidneys.—Next to the lungs and the skin, the most important excretory organs are the kidneys. These are two glandular structures situated within the abdominal cavity at its posterior part. Each weighs from four to six ounces and is about four inches long and two inches wide with a thickness of one and a half inches.

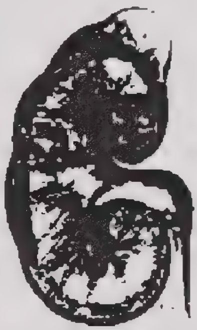

FIG. 145.- SECTION OF A KIDNEY.
a.—The ureter.

The kidneys are made up in great part of arteries, veins, and numerous small tubules, and so far as known, have but the one function, that of excretion. They remove from the blood much water, many salts, and considerable organic waste matter, the chief constituent of which is *urea*, a substance also contained in the perspiration excreted by the skin. From each kidney there proceeds a tube about the size of a goose quill, called the *ureter*, which passes downward to the bladder. Through these tubes the excrementitious matter from the kidneys passes into the bladder, which acts as a reservoir for it. The average amount of excretion from the kidneys is about three pints daily.

366. Summary.—By way of summarizing what has been said about the excretory organs, it may be pointed out that the lungs (in their excretory functions), the skin, and the kidneys, are "all engaged in the great

task of ridding the system of its superfluous matters, and that each supplements the actions of the others. The lungs are great excretors of carbonic acid, though they share with the kidneys and the skin the task of getting rid of water. The kidneys have thrown upon them the task of removing from the system nearly the whole of the nitrogenous waste products and the superabundant salts, besides being the greatest excretors of water. The skin, on the other hand, looked upon as an excretory organ, is second in importance to the kidneys as a remover of water, and comes next to the lungs in separating carbonic acid. The skin, it must be remembered, however, has many functions. Besides being an organ of sense it takes the chief part in regulating the temperature of the animal body."*

367. Disturbances in the Functions of the Excretory Organs.—The excretory functions of the lungs, the skin and the kidneys may become deranged or partially destroyed from a variety of causes. Inflammatory diseases of the lungs and air passages, as bronchitis and pneumonia, interfere with the excretory functions of these organs, often causing serious disturbances to the system by permitting the blood to become overloaded with carbonic acid gas.

The excretory functions of the skin may be hindered by sudden chilling and by high fever. Severe injuries to the skin, as burning, also affect its action. Uncleanliness of the skin interferes with the proper excretion from this organ because of the ducts of the glands being clogged up with waste matter. Inflammatory condi-

* Professor Arthur Gamgee.

tions of the kidneys interfere with the proper excretions from these organs. A severe cold often produces a condition which hinders the work of all the excretory organs, and in such cases a dangerous disturbance is produced in the entire system.

368. The chief function of all the excretory organs is to remove from the system such substances as are useless and injurious and which, if allowed to remain in the circulation, would produce disease and death. Any interference with this function is therefore likely to cause not only distress and pain in these organs themselves but also a general derangement of other parts concerned in the conduct of the various life processes. Alcohol being in the highest degree injurious to all the tissues with which it comes in contact, these excretory organs are charged especially with its prompt removal.

How do the lungs remove alcohol from the blood (§ 351)? Do they remove it all? What very common evidence do we have that they remove a portion of it, even in the case of moderate drinkers? How are the lungs and air passages themselves affected by contact with alcohol? If the lungs do not remove all the alcohol from the system what other organs must assist them? Does any alcohol remain permanently in the circulation? If this were the case, what would be the effect upon the tissues?

369. The kidneys are all the time separating and removing unusable substances which have in various ways found access to the vascular system. Their work, like that of the lungs, is continuous, but it is different in that they carry off some substances which the lungs cannot carry off. During the process of digestion

certain food substances which have not been perfectly digested find their way into the circulation. The liver, in its healthy and normal condition, aids to some extent in digesting these substances and preparing them for use as nutriment. But suppose now that the use of alcoholic liquors has so affected the liver as to change its structure and derange its functions, what becomes of these undigested and unusable substances? They are not only of no service in supplying nutriment to the body, but so long as they remain in the general circulation they are a detriment and act as a poison. It therefore devolves upon the kidneys to remove them. This they endeavor to do, but being already occupied in their proper function of removing the excretions to which we have alluded (§ 365), they are now overburdened with work and finally break down under the strain. Serious disorders of the kidneys are the result, ending frequently in incurable and fatal diseases.

It is the opinion of many physiologists that that terrible affection known as Bright's disease is often, though of course not always, caused by the use of alcoholic liquors. Granular degeneration of the kidneys is one of the frequent effects of alcohol, sometimes occurring even in those who indulge in liquors only to a slight degree. Fatty degeneration of the kidneys similar to that which affects the heart and the liver is also to be ascribed to the direct action of alcohol. Catarrh of the bladder, arising from the use of beer or other malt liquors, is not uncommon.

370. In summing up we perceive that the excretory organs are liable to a threefold injury from alcoholic liquors: First, the delicate membranes which form a

considerable portion of their structure are inflamed and disabled by contact with the alcohol in the circulation. Second, the action of alcohol upon the stomach and liver causes the presence of a larger proportion of useless matter in the blood and consequently overworks those organs whose function it is to remove such matter from the system. Third, in addition to the impurities which naturally occur, these organs must also promptly remove the alcohol itself, and are thus doubly overworked. Under such circumstances the only wonder is that they are able to perform any of their functions for any considerable time.

371. Tobacco also Injures the Excretory Organs.— What effect does tobacco sometimes have upon the mouth, throat, and air passages? Is it not probable that the delicate lining membrane of the air vesicles also suffers from this cause? What effect would this have upon the lungs as excretory organs?

The injurious effects of tobacco upon the kidneys are very marked. All tobacco contains an active principle called *nicotine*, which is a deadly poison. If all the nicotine contained in a single cigar were taken into the stomach it would produce instant death. No one can chew tobacco or smoke it without a small portion of this poison finding its way into the system. Upon a person not accustomed to its use even this small portion has its effect, producing nausea and a deathly pallor. If tobacco leaves are bound around the body next to the skin, the skin will absorb a sufficient quantity of the poison to produce a similar result. Deaths caused by the presence of this subtle drug are of frequent occurrence.

Now the nicotine which finds its way into the system

of the smoker or chewer must be expelled or it would soon accumulate in quantities sufficient to cause death. How shall it be expelled except by the excretory organs? A small portion of it is expelled by the lungs, as is shown by the fact that the smoker's breath carries always an odor of tobacco. But by far the larger part is carried off by the kidneys, and these are liable to become seriously affected by its influence. Bright's disease is sometimes a direct result of injuries to the kidneys produced by the tobacco habit. Sometimes the kidneys are unable to remove the poisonous nicotine as fast as it finds entrance into the circulation and then it must be expelled through other channels. In such cases, not only the blood, but the muscles and the secretions become saturated with tobacco. The skin and the lungs assist so far as possible in removing this condition. As a consequence the penetrating odor of nicotine is constantly being exhaled from the body of the individual, although he may have abstained for several days from the use of tobacco. The poison penetrates into and affects every organ, even the nerves and the brain, benumbing the sensibilities and preventing the individual from realizing his condition.

XXXVII.—HOW THE BODY IS KEPT WARM.

372. Bodily Heat.—The degreee of heat which exists at all times within the body, independent of external influences, is called animal heat or bodily heat. This heat is developed during the process of

nutrition, and is nearly the same in cold and in hot weather. The maintenance of proper bodily heat is necessary to life, and if from any cause the body is unable to generate sufficient heat in cold weather or to moderate it in hot weather death will result.

373. The normal temperature of man in temperate climates is 98.5 deg. F., and this varies but slightly in the healthy body. Even in very cold or very hot climates the bodily temperature deviates but little from this.

In different parts of the body the temperature varies and in some of the internal organs the blood is considerably warmer than it is upon the surface of the body. It has also been found that the general heat of the body varies under certain conditions, as during times of rest or activity, of sleep, of digestion, or of intense nervous excitement. While the body is being exercised, the heat is greater than when it is at rest. During digestion the bodily heat is increased and certain articles of diet, especially fats, tend to increase this heat considerably. The elevation of the external temperature increases the bodily temperature and the lowering of it decreases it. All changes, whether increasing or diminishing the bodily heat, are, however, but slight.

374. Sources of Animal Heat.— Experiments have shown that no particular organs are endowed with the special function of producing heat. The production of heat within the body is a general process and takes place in every tissue. It accompanies the processes of nutrition, and may really be regarded as a consequence of nutrition. Certain kinds of foods (§ 170) seem to be almost wholly concerned in the production of heat.

The starches, sugars, and fats, although of themselves unable to support life or nourish the tissues, are all destroyed in the processes of nutrition and are necessary articles of diet. They are especially craved by persons who are exposed to extreme cold; and in the arctic regions they are the most important of foods.

Nevertheless, these articles of diet are not absolutely essential to the production of animal heat, for the body, when denied them, still continues to maintain its warmth. We are accordingly prepared to learn that the process of respiration is doubtless the principal agent in the production of animal heat. Respiration is not only an excretory process, but it is also a nutritive process in that it is the means of supplying oxygen to the tissues (§ 340). The consumption of oxygen by the tissues—oxidation—and the giving off of carbonic acid gas, has at all times a direct ratio to the amount of animal heat produced.

Oxidation within the body is, in fact, a process of combustion similar in its nature to the combustion of fuel. The worn-out tissues, the broken-down cells are, in a certain sense, burned up—the carbon, hydrogen, and nitrogen which they contain uniting with the oxygen and producing carbonic acid, a little water, and the evolution of heat. This oxidation takes place within the tissues and is intimately and mysteriously connected with the processes of assimilation and nutrition.

375. How the Bodily Temperature is Equalized.—It is necessary for the health and comfort of the body that its temperature be kept approximately the same under all conditions. This is accomplished largely

through the aid of the skin by means of perspiration (§ 362). There is always a greater or less loss of heat by evaporation from the surface of the skin. In hot weather this evaporation is very considerable and the amount of heat removed from the body is much greater than in cold weather. Nevertheless, loss of heat being, to a certain extent, constant, the body requires to be properly clothed according to the variations in the climate.

376. The Clothing.—One of the objects of clothing is to keep the system at a uniform and comfortable temperature. The temperature of the body varies but slightly at different seasons of the year. In cold weather an abundance of clothing is required in order to retain the bodily heat; in hot weather the evaporation of perspiration upon the skin prevents too high a temperature.

377. Effects of Alcohol upon the Animal Temperature.—It is not unfrequently claimed that the use of alcohol tends to increase the bodily heat, and people are sometimes advised on cold days to drink something "to help keep them warm." This is a mistake, for alcohol neither produces animal heat, nor indirectly causes its increase. It acts probably in the opposite way, diminishing the amount of bodily heat and causing the system to be more susceptible to changes of temperature. Certain it is that persons who use alcohol are unable to resist either great heat or great cold. Oxidation and nutrition are, as you have learned, essential to the production of animal heat. The use of alcohol interferes with both these processes, and this, no doubt, results in the diminished production of animal heat.

XXXVIII.—THE NERVOUS SYSTEM.

378. **The Engine and the Engineer.**—One of the most wonderful of all mechanical inventions is the steam engine. You have noticed the great number of its parts and the complexity of its construction. You have observed with what exactness each part performs its particular office or function, and how readily it responds to the controlling hand of the engineer. Perfect as it may be in its mechanism and adjustment, and wonderful as is the work it is able to perform, you know that without the regulating and restraining influence of the engineer it would be useless—a mere collection of inert pistons, wheels, and levers, incapable of action. The boiler may be filled with water, fire may be kindled beneath it, steam may be generated—and yet the engine will remain helpless and useless.

Now, the living body may, in a certain sense, be regarded as an engine—the most wonderful of all engines — with its parts perfectly arranged and adjusted, and each part adapted to some special function upon the performance of which the well-being of the whole depends. The three great systems of digestion, respiration, and circulation act in unison to maintain the life and promote the health and strength of the tissues; all the vital processes are performed with exactness; in the action of the various organs there is a wonderful harmony. Whence comes this unison, this exactness, this harmony of action? Where is the

engineer by whom this wonderful mechanism is directed and regulated?

That system of organs and parts which controls and harmonizes all the other systems and life processes is called the *nervous system.* It performs its functions by means of central organs composed of nervous tissue, together with innumerable nerves which extend to and traverse every portion of the body. Let us briefly study some of the facts relating to this wonderful system.

379. Nervous Tissue.—The substance of which the nervous system is constructed is called *nervous tissue.* It is of two kinds, each differing from the other in composition and in appearance. One is white and of a fibrous structure; the other is gray, cellular, and of a soft consistency. The former is composed of small fibers, and serves as a *conductor* of nervous impressions; the latter is made up of nerve cells, and serves as an *originator* of nervous impressions or of nerve force. Nerve force originates in *nerve centers;* and these are masses of gray matter. This force, when conducted to the muscles, is what causes them to contract. The masses of gray matter are therefore the centers from which motion of all parts of the body originates.

FIG. 146.—A NERVE CELL. (Highly magnified.)

380. The Gray Matter.—Each of the cells of which the gray matter is made up consists apparently of a soft, granular substance. These cells vary greatly in size and in shape, some being round, some oblong, and others irregular or star-shaped. Issuing from

each are usually one or more tail-like processes, which connect directly with nerve fibers. The gray nervous tissue exists in the brain and spinal cord, where it forms masses of matter called *nerve centers* or *ganglia*.

381. The White Matter.—The *white* or *fibrous* nerve tissue is made up of numerous thread-like structures called nerve fibers. It is of a glossy white appearance and has a firm consistence.

The nerves are composed of white nerve tissue. This tissue also exists abundantly in the brain and spinal cord.

382. Divisions of the Nervous System.—The nervous system consists of two grand divisions, each having a distinctive character of its own and performing functions peculiar to itself. The first of these grand divisions is called the *cerebro-spinal system;* it consists of the brain and the spinal cord, with the nerves which have their origin in them. The second is called the *sympathetic system;* it consists of a chain of ganglia or nerve centers, and the nerves which originate from them. The former system is directly connected with the intellect and presides over all voluntary movements. The latter controls and regulates all those functions that are connected with the various nutritive processes, as digestion, circulation, secretion, and excretion.

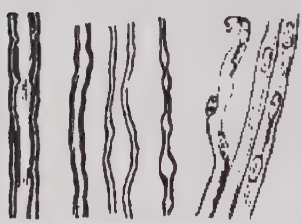

FIG 147.—NERVE-FIBERS. (Highly magnified.)

383. The Cerebro-Spinal System.—The cerebro-spinal axis, from which all the cerebro-spinal nerves originate, consists of two parts, the *brain* and the

spinal cord. The brain is the mass of nervous tissue—both gray and white—which is contained within and fills the cranial cavity (§ 53). The spinal cord is the mass of nervous tissue which is contained within and fills the spinal canal (§ 43).

The brain and the spinal cord are connected with each other, the latter appearing to be a continuation of the former, emerging from the cranial cavity through an opening in its base (the *foramen magnum*) and passing downward through the entire length of the spinal canal.

The entire cerebro-spinal axis is surrounded and enveloped by a strong membrane arranged in three layers, which serves as a protection to the nervous tissues, and as a support for the numerous blood vessels which supply them with nutrition.

The cerebro-spinal axis is composed of both white and gray nervous tissue. The gray matter is arranged in masses which form a chain of nerve centers or ganglia, and the white matter is so arranged as to connect together these different ganglia. The ganglia, it must be remembered, serve as originators of nerve force, the white matter serves as conductors of nerve force (§ 382).

XXXIX.—THE BRAIN.

384. The brain, or *encephalon*, consists really of a number of ganglia, or nerve centers, united to one another by means of white, or fibrous nerve tissue. It is connected, directly or indirectly, with all the nerves

of the body. It is composed of both gray and white matter, the gray matter being without, and the white matter within. The gray matter is arranged in rolls or convolutions, thus increasing its surface and quantity.

The brain comprises three parts or divisions, the *cerebrum*, the *cerebellum*, and the *medulla oblongata*. These are all connected with one another and with the spinal cord.

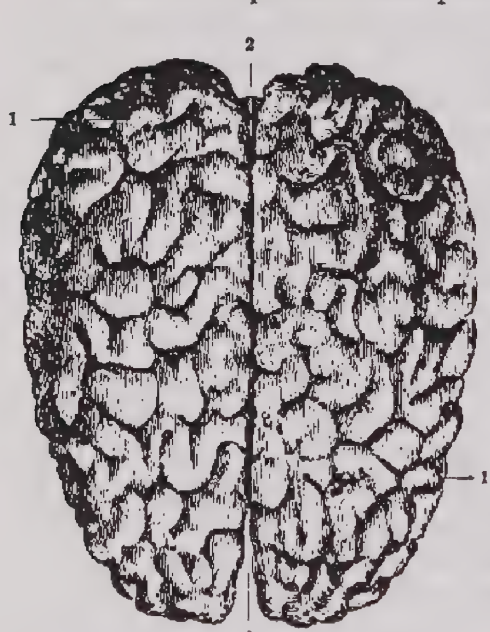

FIG. 148.—VIEW OF THE TOP OF THE BRAIN. 1, 1.—Hemispheres. 2, 2.—Longitudinal fissure.

The brain of man is more highly developed than that of any other animal, and in proportion to the size of the body, is larger. In man the average weight of the brain is equal to about one fortieth of the weight of the body; in the lower animals it equals only about 1-180 part of it.

385. The Cerebrum.—The cerebrum is the largest division of the brain, comprising more than four fifths of its entire mass. Its surface is not smooth, but, as stated above, consists of numerous folds, or convolutions. It is divided by a deep longitudinal fissure into two lateral halves, called hemispheres of the brain.

Each of these hemispheres is divided, by shallower fissures, into three lobes, an anterior, a middle, and a posterior.

The gray matter in the cerebrum lies externally, varying from one twelfth to one eighth of an inch in thickness, and, as already stated, is arranged in convolutions or wave-like folds. The white or fibrous tissue lies internally, and imbedded in it are certain masses of gray matter, or ganglia. The white matter serves as a connector as well as a conductor between the masses of gray matter, and the arrangement of the fibers composing it is very complex and intricate.

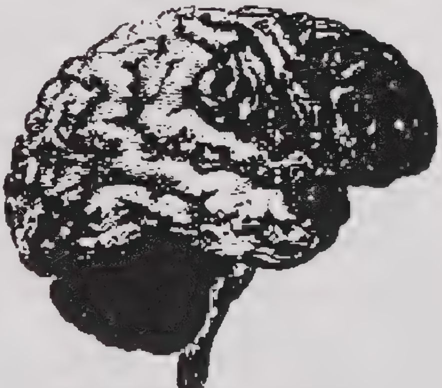

FIG. 149.—SIDE VIEW OF THE BRAIN.
A.—Cerebrum B.—Cerebellum.
C.—Medulla oblongata.

386. Functions of the Cerebrum.—The cerebrum is the seat of the mind. It is a necessity to all acts and processes connected with life. All the operations of thought are dependent upon it, and disease or destruction of its tissues results in the diminution or complete annihilation of the intellectual powers. Brain tissue, by use, wears out, just as other tissues do. It therefore requires nutrition for its regeneration.

Not only do all intellectual processes have their origin in the cerebrum, but it is from this part of the brain that all voluntary motions are directed, and their motor stimulus is produced. Thus, injury or

disease of some parts of the cerebrum produces loss of motion or sensation in certain parts of the body. Injury or disease in other parts causes, and is followed by, feeble and inadequate thought and failing intellectual powers.

In general terms it may be stated, that intellectual power exists in man in proportion to the size of his cerebrum and the delicacy of its organization, although there have been marked exceptions to this rule. In the cerebrum is also a center which presides over the power of articulate language. If this center is diseased or injured the person loses his power of articulate speech, although he may remain in full possession of his mental faculties and be able to think and to write intelligently.

Scientists have observed and noted the effects which follow a removal of the cerebrum from animals. It has been found that, although the creature continues to live, a marked change takes place in its appearance and movements. It becomes stupid and utterly indifferent to its surroundings. It still possesses the power of motion and sensation, but does not use these powers. It probably sees and hears, but connects no idea with anything seen or heard. It may feel thirsty or hungry, but has no idea of quenching its thirst or satisfying its hunger. It has no fear and hence has no idea of escaping any form of danger. In short, its intellectual powers are completely lost.

387. The Cerebellum.—The cerebellum, or little brain, lies beneath the back part of the cerebrum and is joined to it. Its weight is about five ounces. It is composed of both white and gray matter, the gray matter lying external, and the white matter internal.

Its surface is rough, being marked with numerous small, fine convolutions, which dip deeply into it, giving its section a peculiar leaf-like appearance. The cerebellum is more highly developed in man than in any of the lower animals.

388. Functions of the Cerebellum.—From observations and experiments it has been demonstrated that a chief function of the cerebellum is the regulation of movements. This portion of the brain presides over all coördinated movements, that is, those movements requiring the concerted contraction or relaxation of different muscles. It does not act as the cause or originator of such muscular movements, but rather as the controller and restrainer of them. If the cerebellum is injured or diseased so as to affect or derange its functions, those movements requiring a concerted action of several muscles are not produced as they should be.

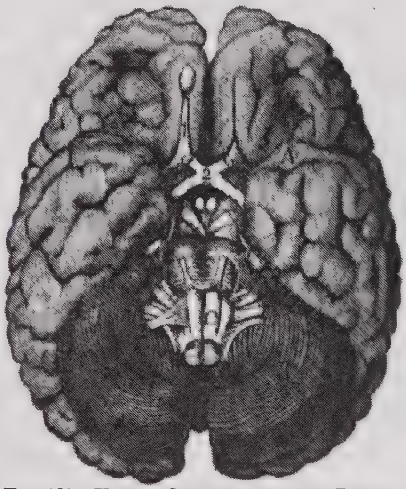

FIG. 150.—UNDER SURFACE OF THE BRAIN.
A.—Cerebrum. B.—Cerebellum.
C.—Medulla oblongata.
1.—Olfactory nerves. 2.—Optic nerves.
The origins of other cranial nerves are also shown.

389. The Medulla Oblongata.—This is the smallest division of the brain. It is oblong in shape and measures about an inch and a quarter in length, and an inch in width. It consists of a mass of white matter, within

which is imbedded a small mass of gray matter. It serves to connect the brain with the spinal cord.

390. One of the functions of the medulla oblongata is to act as a conductor of sensations and motor stimulus between the brain and the spinal cord. Its most important function, however, is in its connection with the acts of respiration. These acts are controlled entirely by the ganglion, or collection of gray matter, within the medulla oblongata. This ganglion, because it is so intimately connected with the maintenance of life, is aptly called the "vital point." If it is destroyed, or even injured, the acts of respiration cease and death speedily ensues.

FIG. 151.—SECTIONAL VIEW OF THE BRAIN.
A.—Cerebrum.
B.—Cerebellum.
C.—Medulla oblongata.
D.—Fibers connecting the two hemispheres of the brain.

391. Hygiene of the Brain.—The hygiene of the brain is most important. The mental and moral nature of a person is dependent upon the condition of his brain and nervous system. Proper exercise of the brain is as essential to the welfare of this organ as muscular exercise is to the muscles. Brain exercise, like muscular exercise, must not be carried to excess. The brain should not be overtaxed by excessive study, nor should it be enfeebled by too little exertion or

mental effort. Proper muscular exercise and good, nutritious diet are also necessary to a healthy brain. If the general system is weak and unhealthy it follows as a natural consequence that the brain power will be feeble. A sound mind must have a sound body to dwell in. Pure air, and plenty of it, conduces greatly to the health and activity of the brain. Mental worry, a free vent to the emotions, as anger, hatred, jealousy, etc., and violent mental excitement all tend to weaken the mental powers and to exhaust the nervous system.

Self-control is a faculty which should be cultivated by all. It aids in the formation of a healthy, clean mind, and does much toward producing a strong nervous system.

392. How Alcohol Affects the Brain.—When alcohol gains access to the blood-vascular system, the blood with which it mingles carries it quickly to all parts of the body. Before the lungs and other excretory organs can remove it from the system no inconsiderable portion of it is carried to the blood vessels of the brain. There it acts as a powerful disturbing element, deranging the action of the nerve centers, causing various disorders of the nervous tissue, and frequently producing intoxication. Its direct action upon the substance of the brain is somewhat similar to that which it has upon other tissues, producing inflammation and congestion, and changing its substance so as to prevent the full exercise of its powers. Physicians who have examined the brains of persons who have died from accident or disease tell us that it is easy to distinguish the brain of a drunkard; it is harder and more resistant to pressure, and when removed from the cranium preserves

its form better than the healthy brain of a temperate person. Sometimes, however, a softening of the brain occurs, particularly in the gray matter. In other cases, by reason of the liquor having already caused derangements of the lungs, heart, or kidneys, the brain substance becomes distended with accumulations of serous fluid. These conditions, as would naturally be supposed, are attended with many distressing symptoms, as sleeplessness, delirium, impaired sensibility, and stupor; if not relieved or removed, they finally end in death.

393. Alcohol and the Moral Sense.—The use of alcohol, through its action upon the brain, produces disastrous effects upon the mind and perverts and enfeebles the moral sense. "Sentiments of honor, of dignity, of reputation, and of decency cease to be cherished or regarded. The amenities of social life and the proprieties of personal conduct are set at naught. Negligence of duty, selfishness, and indifference to the sentiments of honor characterize the indulger in alcoholic drinks. Gradually he loses all right conceptions of justice, of honor, and of truth. The sense of obligation to family and friends is forgotten. If his own wants and especially his craving for drink are gratified, the necessities of those formerly dear to him are no longer regarded. Aversion and hatred frequently take the place of love and esteem. The man who was once reasonable and patient becomes peevish, perverse, and irritable. Finally he grows indifferent alike to the joys and sorrows of life; his moral sense is completely lost, and his conceptions of right and wrong are as vague and indefinite as are those of a brute." It is this effect of alcohol upon the moral sense which makes criminals

of men who would otherwise be gentle, kind, and law-abiding citizens. Indeed, the majority of those who fill our prisons are persons addicted to the alcohol habit, and most of the crimes that are committed against law and order are directly traceable to the influence of strong drink.

394. Alcohol and the Intellect.—Through the use of alcohol the brain is so affected that intellectual power is diminished and frequently lost. The slave to alcohol is not inclined to mental exertion of any sort. He gradually loses the power of consecutive and sustained thought upon any subject. It is hard for him to maintain a conversation upon even the most commonplace topics. He is unable to comprehend his own degradation, and still he has no sense of self-respect. Finally, his memory begins to fail, his powers of reasoning and of judgment are lost, and he becomes unfit to maintain the ordinary relations of life with his fellow men. This condition, it is well to remember, has been brought about by the action of alcohol upon the tissues composing the organs that are concerned in the various life processes, thereby interfering with the nutrition of those organs, and of the entire system, deranging the action of the nervous system, and disturbing the brain itself.

395. Alcohol and Insanity.—Alcohol is the most common cause of insanity. It is estimated that from fifteen to twenty per cent of all the cases of mental disease are directly traceable to the effects of alcoholic drinks. One of the most frequent forms of alcoholic insanity is that known as melancholia. This is accompanied by hallucinations chiefly of hearing. The patient is terrified by fancied accusing or threatening voices, and is often

impelled to self-destruction. Mania, chronic delirium, and dementia, are other forms of alcoholic insanity, and these frequently end only in death.

396. The Alcohol Habit and Heredity.—The appetite for alcoholic drinks, like other traits of body and mind, is often transmitted from parents to their children. In some cases the tendency may be transmitted directly from one generation to another; in other cases it may pass over one or more generations, appearing in the intermediate periods in some other form. Sometimes the descendants of drinking parents have no special appetite for alcoholic beverages, but are affected with all the symptoms of chronic alcoholism; that is, the results of the gratification of the alcohol appetite are transmitted, but not the appetite itself. It is not uncommon to find in such persons perverted sensation, nervous diseases, and indeed all the symptoms of intoxication, even though they may abstain entirely from drink. The children of persons addicted to indulgence in alcoholic drinks are often puny and diseased and feeble, both in body and in mind.

397. The Nerves Are Injured by Alcohol.—What effect does alcohol have upon the voluntary muscles (§ 104)? What disorders of motion are attributable to the effects of alcoholic liquors? What names are given to the nerves which regulate the movements of the heart (§ 281)? How does alcohol affect these nerves?

The use of alcoholic liquors soon has its effects upon the nerves, producing disorders of general sensibility which vary in their intensity from mere feelings of discomfort to paroxysms of pain. Often the sensibility of the muscles is impaired or destroyed; at other times there is an increased sensibility to pain, such that even

the slightest contact with other objects will produce discomfort. Paralysis of different organs and parts of the body often occurs. The indulger in alcoholic drinks is also a frequent sufferer from neuralgia due to the effects of the poison upon the delicate structure of the nerves.

398. Tobacco Injures the Brain and Nerves.—A very frequent cause of injury to the nervous system is the use of tobacco. What poisonous element does tobacco contain? By which of the excretory organs is it largely removed? How does nicotine affect the nerves of the heart (§ 282)? How is this likely to affect the nutrition of other parts?

Tobacco affects the nutrition in another way. By causing a constant nervous irritability the action of all the organs concerned in the conduct of the life processes is somewhat deranged, the circulation is impeded and assimilation is retarded. Often the inveterate tobacco user becomes pale, nervous, and thin; but if he should give up tobacco he would probably again become hale and hearty.

399. Cocaine is a poisonous drug, the use of which is comparatively modern. The effects of this drug upon the body are in many ways similar to those of opium. The cocaine habit is even more difficult to overcome than the alcohol habit. The use of this deadly drug is quickly followed by harmful results. The body and mind are, in a very short time, completely wrecked, and insanity and death speedily follow.

400. Opium, Chloral, and similar drugs are dangerous to the life, but being sleep-producing agents, are often resorted to by persons to such an extent that after a

time their use becomes a habit which is most difficult to overcome. All such drugs have a harmful effect upon the system, interfering in various ways with the life processes and doing permanent injury to vital organs. They render the user weak and unhealthy, both physically and mentally. They should never be used except by the order of a physician who can closely watch their effects.

XL.—THE SPINAL CORD.

401. Where is the spinal cord situated? How is it protected? What is the spinal column? Of what is it composed? How is it united with the cranium? How are the vertebræ united with one another?

The spinal cord is composed of the nervous tissue situated within the spinal canal. Its length corresponds with that of the spinal canal, and it terminates in its lower part in a slender gray filament. The weight of the spinal cord is about one and a half ounces. It is divided, by means of fissures running longitudinally, into different sections, called *columns* of the cord, each of which has its peculiar functions.

402. The spinal cord acts as a conductor of sensations and motor stimulus, between the brain and the spinal nerves. The fibers which do the conducting, cross each other at the base of the brain, in the medulla oblongata, those from the right side of the cord going to the left side of the brain, and *vice versa.* Thus it happens that an injury to one side of the brain may produce paralysis of the opposite side of the body.

Fig 152.—Section Showing the Brain and Spinal Cord.

Besides acting as a conductor, the spinal cord also acts, by virtue of its gray matter, as a nerve center. In the cord, the white matter lies external, the gray matter internal. How do they lie in the brain?

403. **Reflex Movements.**—As a nerve center, the spinal cord is capable of originating nerve force, and by this, of producing movements. These movements are of a peculiar kind called *reflex*, and are entirely independent of the brain, and therefore of thought and of the will. If the cord becomes diseased or injured so that its connection with the brain is interrupted, all power of voluntary motion is lost in the lower part of the body. Reflex motion, however, still exists, and by certain irritations or stimuli

this class of involuntary movements continues to be produced.

404. A Few Examples of Reflex Motion.—The sudden application of heat or cold to a part of the body causes certain muscles to contract, thus removing the part from the source of irritation.

The expectation or danger of injury often causes the sudden throwing up of the hands.

A sleeping person will frequently roll and toss, being totally unconscious of such movements.

An unconscious person will sometimes swallow water, if it be put to his lips.

Reflex movements, then, are a peculiar class of movements produced independently of any action of the brain, and without the concurrence of thought or of the will. They are of much importance in the vital economy, especially in protecting the body from external injury.

405. Practical Review.—If the different parts of the digestive system should fail to perform their functions harmoniously, what would be the result?

If the heart should fail to send its venous blood to the lungs, or if the lungs should fail to inhale oxygen for the purification of the blood, what would follow?

What system of organs and parts brings about the harmonious performance of all these vital processes?

Can the heart say to the head, "I have no need of you," or the head say to the heart, "I have no need of you"? Why? Explain fully.

What part of the brain is exercised most while studying deeply upon some subject requiring thought?

Describe how the brain assists one in walking.

What names are applied to the two general divisions of the nervous system?

From what two words is the word *cerebro-spinal* derived? What is its meaning?

What are the two chief centers of the cerebro-spinal system? By what is each inclosed and protected? What forms the connecting link between them?

It is believed by physiologists that alcohol, having once found its way into the blood, circulates throughout the whole organism, being the most abundant in those parts which are the most abundantly supplied with blood. About one fifth of all the blood in the circulation goes to the brain. This being so, which of all the organs is likely to suffer the most from the effects of alcoholic liquors?

Physicians have detected alcohol in the blood vessels and the thoracic duct within a minute and a half after it was taken into the stomach. How soon after strong liquor is drunk are its effects likely to be apparent in the brain? Explain.

Since alcohol is so injurious to the brain substance, is it reasonable to suppose that the spinal cord is not also seriously harmed by it?

XLI—THE NERVES.

406. By what means do the brain and spinal cord exert their controlling influence over other parts of the body (§ 378)? In our study of the bones, the muscles, the great nutritive systems, and indeed nearly all the various tissues comprising the human system,

we have everywhere observed the presence of nerves. With the exception of only the epidermis, the hair, and the nails, there is no portion of the body in which they are entirely absent. It is through them that the cerebro-spinal centers are informed of the condition and necessities of all the organs and tissues; it is through them that these same centers exercise their regulating and controlling influence.

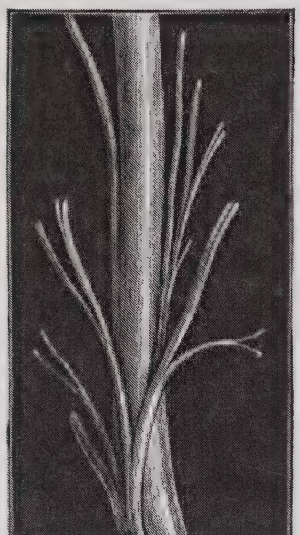

FIG. 153.—A NERVE AND ITS BRANCHES.

407. **Illustrations.**—The brain may be likened to the central office of a complex telegraph system; the nerves to wires conveying information and commands to and from innumerable outlying stations. Suppose that, in the mind, a wish to walk is conceived. Immediately from that portion of the brain which has control of locomotion, the proper stimulus is conveyed through the nerves to the exact muscles that must be set to work to produce the desired movements. At the same time the cerebellum exercises its powers to regulate and harmonize the action of the muscles, so that each performs its functions at precisely the right time and in precisely the right manner.

Suppose that a needle accidentally pricks your finger. However fine its point may have been, the nerves are everywhere so thickly interlaced that at least one must have been touched by it. Instantly that nerve tele-

graphs to the brain the news of the injury, and as instantly the brain sends to the muscles of the hand and the arm the stimulus which causes the quick removal of the finger from the place of danger. It is all done so quickly that thought has no part in it.

408. Structure of the Nerves.—Now let us learn something about the structure and peculiarities of these channels of nervous impressions and influence—the nerves. To the eye, such as can be seen appear as white, glossy cords of various sizes, dividing and subdividing into branches which are distributed to all parts of the body. These branches soon become too minute to be distinguished by the vision, and too numerous to be reckoned by number. The nerves, whether larger or smaller, are composed of bundles of nerve fibers bound together and enclosed in a fibrous tissue.

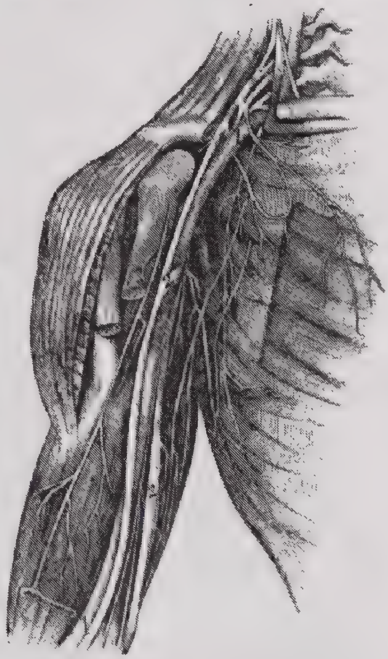

FIG. 154.—NERVES SUPPLYING THE SHOULDER AND ARM.
1, 1.—Artery. 2, 2.—Nerves.

Is nerve tissue of the white variety or the gray? What is the function of the white matter? Of the gray? (§ 379).

409. Classes of Nerves.—According to their proper-

ties nerve fibers are of two classes; those of one class conduct sensation, those of the other class conduct motor stimulus from the centers of nervous power. Nerves of the former class are called *sensory nerves;* those of the latter are called *motor nerves.*

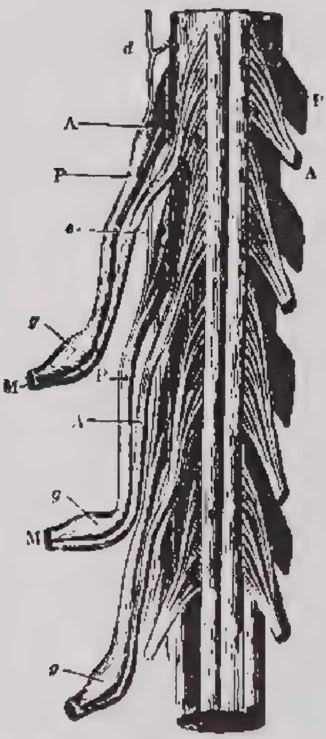

Fig. 155.—How the Spinal Nerves are given off from the Spinal Cord.

A, A, A.—Anterior roots.
P, P, P.—Posterior roots.
c, d.—Filaments passing between the posterior roots.
g, g, g.—Ganglions of posterior roots.
M, M.—Nerves formed by union of two roots.
(The size of the roots is not so large in nature as here represented.)

A nerve is usually a *mixed nerve*, that is, it contains both motor and sensory nerve fibers. Occasionally, however, a nerve is either wholly sensory or wholly motor.

If a nerve containing both motor and sensory fibers be divided, the parts to which that nerve is distributed are rendered incapable of both motion and sensation, until it becomes healed and its parts are united again.

Nerves connected with the cerebro-spinal system are called cerebro-spinal nerves. Those connected with the sympathetic system are called sympathetic nerves.

410. The Spinal Nerves.—Most of the cerebro-spinal nerves have their origin in the spinal cord and are called *spinal nerves.* (Fig. 155.)

The spinal nerves supply approximately all of the

body except the head. They have both motor and sensory properties, that is, they supply the parts with both motion and sensation; and they act as conductors between the spinal cord and the parts supplied by them.

There are thirty-one pairs of spinal nerves, each of which rises from the spinal cord by two roots, an anterior and a posterior. After leaving the spinal canal, the two roots join and their fibers form but a single nerve trunk. The posterior root has upon it a small enlargement which consists of a collection of gray matter forming a small ganglion. This ganglion does not exist upon the anterior root. The fibers which pass through the anterior roots and those which pass through the posterior roots have different characteristics, the anterior set being motor, the posterior sensory.

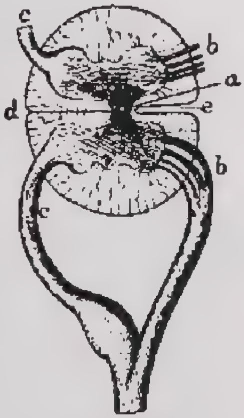

FIG. 156.—ORIGIN OF SPINAL NERVES IN THE SPINAL CORD.

b, b.—Anterior roots.
c, c.—Posterior roots.
d, e.—Fissure dividing the spinal cord longitudinally.
a.—Central canal of the cord.

411. If a spinal nerve be divided, the parts to which it is distributed lose their power of motion and of sensation. If, however, merely the anterior root be divided, those parts lose only their power of motion; and if only the posterior root be divided, they lose their power of sensation, but not of motion. These facts prove beyond a doubt that in the process of conduction, sensations are conducted by the nerve through its posterior root to the spinal cord, and motor stimulus is conducted from the spinal cord through the anterior root of the nerve to the parts.

All voluntary motions derive their motor stimulus from the brain; the motor stimulus which originates in the spinal cord, concerns that class of involuntary movements which are called reflex. What is meant by reflex movement (§ 403)? Give familiar examples of reflex movement (§ 404).

FIG. 157.—SPINAL NERVE COMING FROM THE SPINAL CORD.

412. The Cranial Nerves.—Nerves which have their origin in the brain are called *cranial nerves*. There are nine pairs of these nerves. They serve to supply the head and face with the power of motion and sensation, and also act as special nerves of taste, smell, hearing, and seeing. The anatomy of these nerves, as compared with that of the spinal nerves, is very complex.

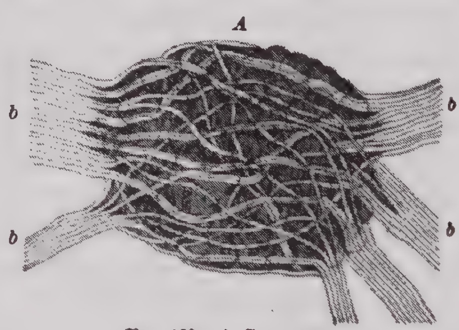

FIG. 158.—A GANGLION.
b, b, b, b.—Nerve fibers coming from it.

Some of the cranial nerves are entirely sensory, some entirely motor, and others both sensory and motor. Those which are known as nerves of special sense are able to conduct to the brain only certain peculiar sensations—taste, smell, sound, light—and are not endowed with general sensibility. Such of the cranial nerves as have sensory properties have upon their roots a collection of gray matter called a ganglion.

The most widely distributed of the cranial nerves is the fifth pair. It supplies almost the whole face with general sensibility, besides supplying most of the muscles of the jaw and mouth. The branch of this pair which supplies these muscles is called the *nerve of mastication.*

413. The Facial Nerve is a part of the seventh pair of cranial nerves. It is a motor nerve, and supplies and presides over the movements of the superficial muscles of the face. It is also called the nerve of expression, for by it the various and numerous facial expressions are made possible. If this nerve should be divided or lose its power of conduction, the face would be rendered expressionless, for its muscles would not then be capable of contraction.

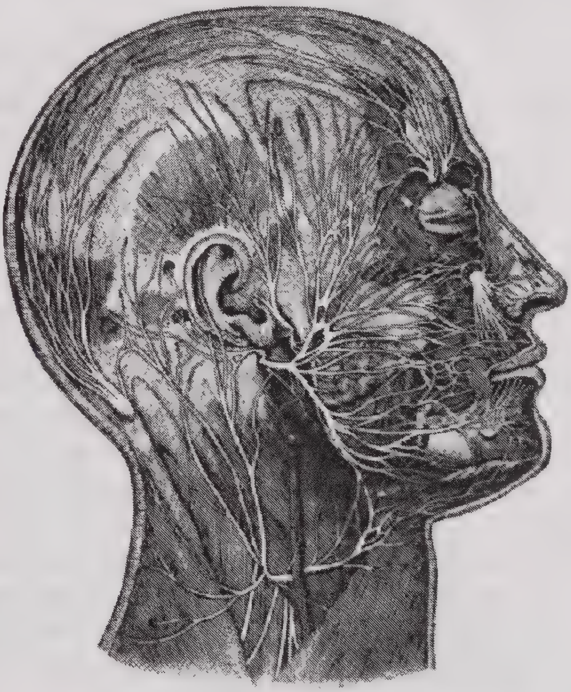

FIG. 159.—BRANCHES OF THE CRANIAL NERVES SUPPLYING THE HEAD AND FACE.

414. Others of the cranial nerves supply other parts of the head and face; the auditory nerve is the nerve

of hearing; the optic nerve is the nerve of seeing, or sight; the olfactory nerve is the nerve of smell.

As before remarked, the minute anatomy of the cranial nerves is very complex, so much so that its further study belongs properly to medical students and specialists.

XLII.—THE SYMPATHETIC SYSTEM.

415. The sympathetic system, like the cerebro-spinal system, is composed of nerves and nerve centers, or ganglia. The ganglia are composed of masses of gray nervous tissue. There are thirty pairs of them, arranged in two chains within the body, one chain upon either side of the spinal column. These ganglia are all united to one another, and from them arise the sympathetic nerves, which, like the nerves of the cerebro-spinal system, are composed of white, or fibrous, nervous tissue. The sympathetic nerves are distributed to the mucous membranes, to the walls of the blood vessels, and to all the organs concerned in the nutrition of the body, as the stomach, intestines, liver, salivary glands, etc. They are distributed to involuntary muscular tissue, and govern its movements.

416. Mention has already been made of that class of sympathetic nerves called vaso-motor nerves. Where are they distributed (§ 300)? What is their special function? What effect does alcohol have upon these nerves (§ 304)? Suppose that their power should be entirely destroyed, how would that affect the circulation of the blood?

417. The sympathetic system governs all acts of secretion and all nutritive processes; it equalizes the circulation of the blood in the body; it has a marked effect upon the maintenance of the bodily heat; and through it certain reflex actions operate.

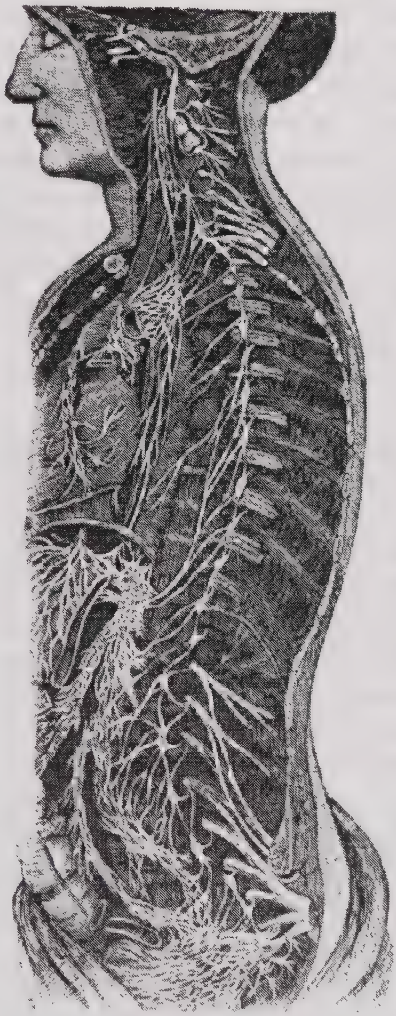

FIG. 160.—THE SYMPATHETIC NERVOUS SYSTEM OF ONE SIDE OF THE BODY. SHOWING ITS CONNECTION WITH THE CEREBRO-SPINAL SYSTEM.

418. Review.—What are the two great divisions of the nervous system?

In what respects do they chiefly differ from each other? In what respects do they resemble each other?

Which of the two acts independently of the will? Are there any parts of the other which so act?

What two kinds of nervous tissue are there? How do they differ from each other in construction; in functions? What part of the nerves controls

or regulates the beating of the heart; the circulation of the blood; the respiration?

What part is active in the operations of the mind; in sudden movement when danger threatens; in the act of chewing food; in the digestion of the food?

Explain how a part of the body may lose all power of motion and still possess sensation. Explain how a part may be affected in exactly the opposite way.

Tell how an injury to the left side of the brain may produce paralysis of some portion of the right side of the body.

What parts of the nervous system compose the cerebro-spinal axis? In what respects do the centers of the cerebro-spinal system differ from the centers of the sympathetic system?

What do you understand by nerve force; by motor stimulus?

What is the nerve of expression?

How many pairs of nerves are there in the cerebro-spinal system? What do you understand by a pair of nerves?

What relative positions have the white and the gray matter in the brain; in the spinal cord?

Of what are ganglia composed? Where are the ganglia of the sympathetic system?

What is meant by reflex motion? Give examples.

XLIII.—THE SPECIAL SENSES.

419. The brain has been spoken of as the seat of the intellectual faculties. It is the organ of consciousness, not only presiding over all the life processes and

voluntary motions, but being the center through which the mind is made cognizant of external objects and phenomena (§ 386).

420. There are five channels by which a knowledge of things apart from ourselves is obtained and impressions of their appearance and character are conveyed to the brain. These are called the *special senses*, or sometimes merely the *five senses*. They are known respectively as (1) feeling or touch; (2) taste; (3) smell; (4) hearing; (5) seeing or sight. Each acts through a set of three structures: an end organ, or peripheral structure; sensory nerves; and a central organ, or the brain.

The end organs through which the sense of feeling acts, are the touch corpuscles of the skin. The end organs of the sense of sight are the eyes.

What are the end organs of the sense of smell; of hearing; of taste?

421. The sensation is received by the end organ; it is transmitted by the sensory nerve; it finds its destination in the brain. A stimulus, no matter of what character, when applied to the special nerves of any one of the organs of sense, excites only that particular sensation for the production of which the organ was intended. For example, a stimulus may be applied to the special nerve of the organ of sight, the eye, either by contact with waves of light, by electrical influence, or by the force of a sudden blow; but in each case the only sensation conveyed to the brain is that of a vision of light. And so it is with the ear, the nose, the tongue, the skin. General sensation also exists in these organs because of the distribution there of sensory nerves.

XLIV.—THE SENSE OF TOUCH.

422. The Skin as an Organ of Touch and Feeling.—Describe the skin as a protective organ (§ 137); as an excretory organ (§ 361). What are the papillæ of the skin? Describe their appearance and arrangement. The sensation of touch resides principally in the skin, where are located the terminal bulbs, or touch corpuscles of the sensory nerve fibers. These corpuscles are in the papillæ.

423. Other surfaces besides the skin—as that of several mucous membranes, of the eyeball, and of the cavities of the nose—possess this sense in various degrees. The terminal corpuscles are much more numerous and lie nearer the surface in some parts than in others; hence the acuteness of touch varies with the location. The eye is exceedingly sensitive, as is also the tip of the tongue. That kind of touch by which we appreciate the form and size of different objects is most highly developed in the hands and especially on the lower, or inner surface, of the fingers.

424. The sense of touch is capable of considerable improvement by persistent education. Blind persons usually have this sense developed to a wonderful degree, being able to appreciate the size and form of objects almost as well by touch as others appreciate them by sight.

425. The sensations of heat and cold are conveyed to the brain chiefly through the touch corpuscles and

the sensory nerves, of which they are the termini. There is also a peculiar power, possessed in a greater degree by some persons than by others, of distinguishing the weight and other physical properties of bodies simply by the touch. This is called by some physiologists the *muscular sense.*

426. It is well to bear in mind the distinction between the sense of touch when the impressions are received through the end organs of the sensory nerves, as above described, and the same sense when the impressions are produced by direct contact with or injury to the sensory nerves themselves. In the latter case it is generally called the sense of *feeling*, but it and touch are only different forms or manifestations of the same sense.

427. Pain.—Feeling may exist wherever there is a sensory nerve. It is the message which these nerves send to the brain informing it of injury or imminent danger to the parts which they supply. In its acute manifestation it is called pain. Touch, in its restricted meaning, exists only on the surfaces of different parts, and its message is rather one of information than of alarm and warning.

Since the impression of touch is received at the end organs of the nerves, the mind generally conceives of feeling as also originating at the nerve extremities. This accounts for the fact that persons who have lost a leg or an arm sometimes, long after the accident has occurred, imagine that they feel pain or a tickling sensation in the toes or fingers which are no longer in existence.

428. How Alcohol Affects the Sense of Touch.—The use of alcoholic drinks has a paralyzing influence

upon the nerves of touch. Experiments have proved that a small quantity of alcohol introduced into the system almost immediately diminishes the acuteness of this sense, rendering the person unable quickly to recognize the contact of an object with the skin.

429. In what respect may pain be regarded as beneficent?

What would be likely to result if there were no such thing as pain?

Name some parts of the body in which the sense of touch is very acute.

Explain the pain which is felt in case of toothache.

Cases are on record of persons who have bathed in water so hot that the cuticle has been removed, and yet without feeling pain. Explain how such can be.

XLV.—THE SENSE OF TASTE.

430. Taste—or gustation—is a sense very closely allied to that of touch. It is more limited in its range, being confined to the tongue and upper and back part of the roof of the mouth and taking cognizance of only certain qualities of substances, as their sweetness, sourness, bitterness, or peculiar flavors.

There are two nerves which preside over this sense and convey the impressions of taste to the brain; one of these is a branch of the eighth pair of cranial nerves, the other a branch of the facial nerve.

431. The Tongue.—Describe the tongue (§204). How does it assist in the mastication of the food? Of what kinds of motion is it capable?

It is supplied with other nerves besides those of taste; for example, the hypo-glossal nerve which supplies its muscular structure is concerned chiefly with its power of motion. Name three different functions performed by the tongue.

432. The mucous membrane of the tongue is a part of the general mucous lining of the mouth. Its upper or free surface is covered with multitudes of minute elevations called the papillæ of the tongue. These papillæ are of various forms, and they are penetrated by the terminal branches of the nerves of taste. In connection with these terminal branches are numerous minute bodies, very complex in structure, called *gustatory bulbs*. It is here that the sense of taste chiefly resides.

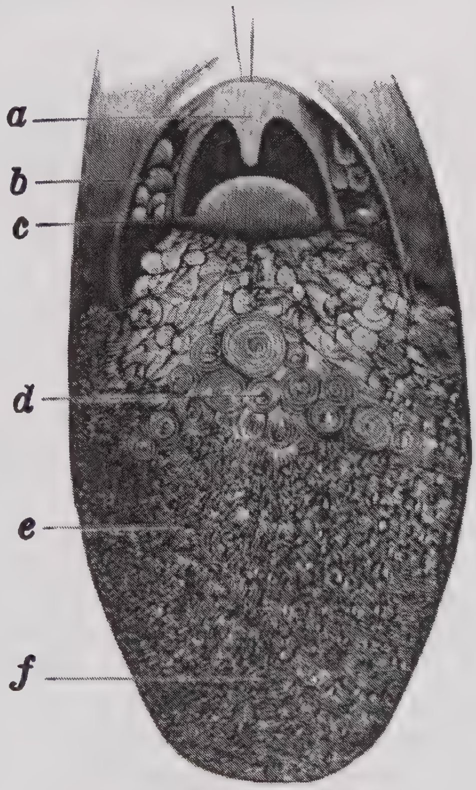

FIG. 161.—THE HUMAN TONGUE.
(Showing also the back part of the mouth.)
a.—The palate. c.—Epiglottis.
b.—Tonsil. d, e, f.—Papillæ.

433. The Quality of Taste.—A substance, in order

to have taste, must be to a certain extent soluble, so that particles of it may be absorbed into the mucous membrane of the tongue sufficiently to reach the gustatory bulbs or terminal ends of the nerves distributed there.

Different parts of the tongue appreciate different kinds of taste; thus one part appreciates sourness, another sweetness, one part saltiness, another bitterness. Some foods are of such a character that their taste or flavor is appreciated by both the sense of taste and that of smell. These substances are said to possess an aroma, which cannot be appreciated by the sense of taste alone. Thus it is that persons whose sense of smell is defective are unable to appreciate the delicate flavors of certain foods.

434. The sense of taste is of great use to us. It enables us to distinguish between wholesome and unwholesome foods, and on account of its close sympathy with the stomach, warns us of those articles against which the stomach will rebel. The sense of taste is also a valuable assistant to the process of digestion; pleasant tastes and flavors greatly increase the flow of saliva, and thus aid in preparing the food for the action of the stomach. This sense can be educated to a great degree. It is very acute in some cases; some persons being able to detect delicate flavors which others can not.

The sense of taste is also often cultivated, so that articles of food which are intensely disagreeable to one person may be very pleasant to another. It may be injured and partially destroyed by indulgence in alcoholic drinks, by the use of tobacco, and in various other ways.

XLVI.—THE SENSE OF SMELL.

435. The Nose.—The sense of smell resides in the mucous membrane of the nose. The nose is really a double organ, its interior being divided by a partition, partly of bone, partly of cartilage, into two parts. The walls of the nasal cavity are formed of bone and cartilage, and are lined by a mucous membrane which is called the *Schneiderian membrane.* This membrane is continuous with the mucous membrane lining the air passages, and is soft and velvety. In that portion lining the upper part of the cavity of the nose are distributed filaments of the special nerve of smell, the *olfactory nerve.* The filaments of this nerve pass downward, from the cranial cavity, through the sieve-like portion of the ethmoid bone. The olfactory nerves constitute the first pair of cranial nerves, and their only function is to serve as the nerve of smell. Any stimulus applied to them is appreciated only as the sense of smell. Branches of the fifth pair of cranial nerves are also distributed to the mucous membrane of the nose and give to it the property of general sensibility.

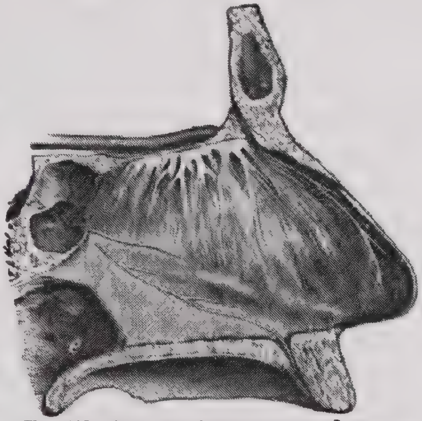

FIG. 162.—SECTION SHOWING THE INTERIOR OF THE NOSE AND THE DISTRIBUTION OF THE OLFACTORY NERVE.

436. From every odorous substance are given off exceedingly small particles of matter, which, being drawn into the nose, touch the mucous membrane where the olfactory nerve filaments are distributed, and there produce a peculiar stimulus, which, being conducted to the brain, is appreciated as smell.

437. Normally, the sense of smell is very acute, but to have a normal sense of smell the Schneiderian membrane must be in a healthy condition. Colds have a particular effect upon this membrane, congesting it and interfering with its functions. The inhalation of irritant gases, as ammonia, and the use of tobacco, either smoking it or using it as snuff, are also detrimental to sense of smell.

In what way does tobacco smoke affect the mucous membrane of the nasal passages? In what way are the nerves generally affected by alcohol? The use of alcoholic drinks tends to impair to a greater or less extent the sense of smell. Persons who have long been addicted to the alcohol habit are very frequently incapable of perceiving even the most powerful odors.

438. The sense of smell is very important to our welfare. Not only does it give us pleasure by enabling us to detect agreeable flavors in food and delicate odors from flowers and perfumes, but it warns us against unfit food, unfit surroundings, and poisonous gases in the air we breathe.

439. The nose being the seat of the sense of smell, and the mouth of taste, care should be taken to keep both these organs in a healthy condition. This condition is much affected by the general health of the body. In order that the sense of smell may be fully exercised it is necessary that the lining membrane of the nose

should be clean and moist. If it is dry or covered with too thick a mucus, as in catarrh, the power of perceiving odors is partly if not entirely lost. One may become so accustomed to an odor, even a disagreeable one, as to become insensible to its presence. This is because the membrane becomes quickly coated with a thin layer of matter which prevents the odor from penetrating to the olfactory nerves. As a general rule, one should avoid either smelling or tasting acrid and irritating substances, for these are sure to affect the delicate nerves of both the nose and the tongue.

XLVII.—THE SENSE OF HEARING.

440. The Ear is the special organ of hearing. Its anatomy is very complex, and we shall describe only its most important features. It is composed of three parts or sections: (1) The external ear, (2) the middle ear, (3) the internal ear.

441. The External Ear.—With the appearance of that portion of the external ear which projects from the side of the head, we are all familiar. This part of the external ear is called the *pinna*, or auricle. It is composed of cartilage, covered over by the skin. From the pinna, a circular canal about one and a quarter inches long proceeds inwards. This canal is called the *external auditory meatus*, and together with the pinna forms the *external ear*.

442. The Middle Ear.—The external auditory meatus extends inwards as far as to the drum of the ear, or *membrana tympani*, and here is situated the *middle*

ear, or *tympanum*. The tympanum is an irregularly shaped cavity situated within the temporal bone between the membrana tympani and the internal ear. At its anterior wall the tympanum communicates, by means of a cartilaginous tube, or canal, with the upper part of the pharynx. This tube is called the *Eustachian tube* and through it, air is admitted to the cavity of the middle ear. Air in this part of the ear is a necessity to the proper conduction of sound. Within the cavity of the tympanum are three minute bones, the *incus*, *stapes*, and *malleus*, which are so united as to form a continuous chain from the membrana tympani to the internal ear.

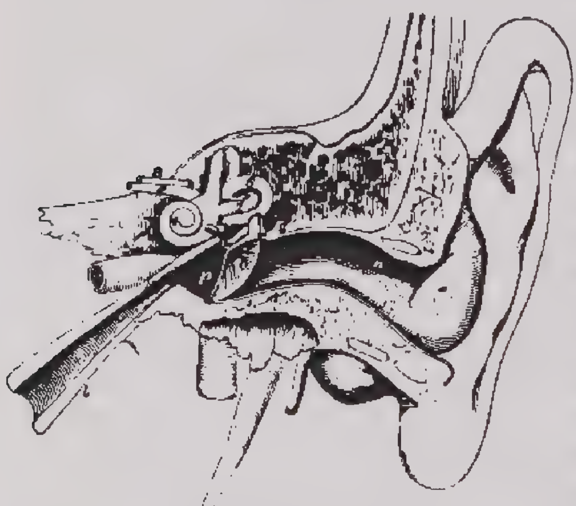

FIG. 163.—SECTION OF THE EAR.

n.—Auditory canal.
o.—Drum of the ear.
p.—Tympanum or middle ear.
1, 2, 3.—Bones of the middle ear.
4, 5, 6, 7.—Internal ear.
8.—Auditory nerve.
l.—Eustachian tube.

443. The membrana tympani, or drum of the ear, is a thin, delicate membrane, stretched across the inner end of the external auditory meatus, separating the external from the middle ear. The outermost one of the small bones is in contact with it, so that when the sound waves are collected by the pinna and are directed

through the external meatus to the drum of the ear, the vibrations here produced are transmitted through the chain of bones to the internal ear. Attached to the small bones are minute muscles, which, by their action, tighten or relax the drum of the ear, thus adapting it to the reception of sound waves of different intensities.

444. The Internal Ear.—The internal ear, called also the *labyrinth*, is situated within the temporal bone, just internal to the tympanum. It consists of three parts, called the *vestibule*, the *semicircular canals*, and the *cochlea*. The vestibule is an oval shaped cavity, communicating in front with the cochlea and behind with the semicircular canals. There are three *semicircular canals*, and these open into the vestibule by five openings. The *cochlea* is a small cavity, resembling in shape a snail shell. Internally it is divided into two parts or chambers which communicate in a curved channel at the top of the cochlea.

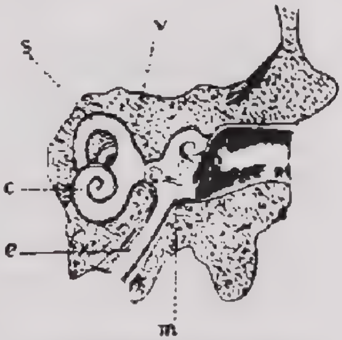

FIG. 164.—SECTION OF THE MIDDLE AND INTERNAL EAR
m.—Middle ear, showing the three small bones.
v.—Vestibule.
s.—Semicircular canals.
c.—Cochlea.
e.—Eustachian tube.

The three cavities comprising the internal ear are bony cavities. Within them are suspended second cavities with membranous walls, which are called membranous cavities, there being a membranous cochlea, a membranous vestibule, and membranous semicircular canals. These are filled with a clear fluid called the

endolymph. The nerve of hearing is the *auditory nerve*, and its filaments are distributed, in a complicated manner, in the walls of the cochlea.

445. The Act of Hearing.—In itself this is a simple operation. Sound results from the action of peculiar wave-like movements in the air, called sound waves. These vary in quality and quantity in different qualities of sound. They are collected by the pinna and directed through the external auditory meatus to the drum of the ear. By their striking upon this, it is made to vibrate; these vibrations are transmitted through the chain of bones in the middle ear, to the liquid of the labyrinth, thence through this liquid to the terminal filaments of the auditory nerve. Here a peculiar stimulus is produced which, being conducted to the brain by the auditory nerve, is appreciated as sound.

FIG. 165.—THE COCHLEA.

446. Deafness may result from a variety of causes. The middle ear may be diseased and transmission of sound vibrations through the bones thus be prevented. The internal ear may be diseased, or the membrana tympani may become ruptured, or the auditory nerve itself may be affected. In general, any condition of the ear which prevents the free transmission of the sound waves or vibrations through the whole ear, interferes to a greater or less extent with the sense of hearing.

447. Injuries to the Ear.—The ear, being an organ of much delicacy, needs the greatest care. Never attempt to clean the ears or remove the wax from them with any pointed instruments, as pins, toothpicks, ear-

spoons, etc. Abrasions leading to serious inflammations may be caused in this way. The use of warm water will serve to remove any surplus wax that may accumulate in the ear.

Care should be exercised not to allow very cold water to enter the ear. The ears should be bathed with warm water, not cold, and should then be thoroughly dried.

Aside from rupture of the ear-drum, there is scarcely a symptom of defective hearing which is not traceable directly to the condition of the nose or throat. It is said that the use of smelling salts is one of the most prolific causes of deafness, operating by weakening the olfactory nerves, and through them the auditory system. All strong or pungent odors should be avoided as far as possible, especially those which act upon the secretory processes, and, as the popular expression goes, "make the nose run."

The use of tobacco often injures the sense of hearing. It affects the throat and the Eustachian tubes, producing an inflammation which extends into the ear, seriously affecting the delicate parts. The use of alcohol frequently has a similar effect. If one would have a delicate sense of hearing he should not indulge in the use of either tobacco or alcohol.

XLVIII.—THE SENSE OF SIGHT.

448. The Eyes.—The eyes are the special organs of sight. They are globular organs situated in the orbital cavities of the skull. They are imbedded in adipose tissue, and attached to them are several small

muscles, which hold them in place and which, by their action, produce the various motions of which the eyeballs are capable.

The eyeball is spherical in form, and consists of a thin wall enclosing a clear, translucent substance. The wall of the eyeball is composed of three layers or coats, an outer, a middle and an internal. (See Fig. 168.)

449. The Sclerotic Coat.—The outer coat is called the *sclerotic coat*. It completely surrounds the eyeball, forming the white of the eye and the transparent portion seen on the anterior surface of it; the latter is called the *cornea*. The sclerotic is the protecting coat of the eye, and is dense and tough in its composition.

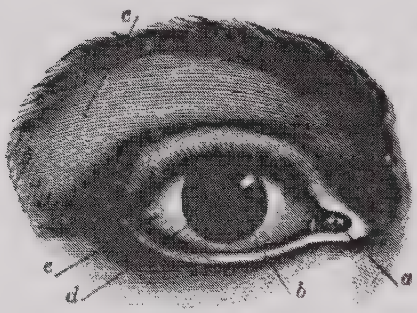

FIG. 166.—THE EYE.
a.—Nasal duct for the passage of tears into the nose.
b.—Cornea.
c.—Position of tear gland.
d.—Pupil.
e.—Sclerotic coat of the eye.

450. The Choroid Coat.—The middle coat is the *choroid coat*. It covers the whole of the eyeball except where the cornea is situated, and lies just internal to the sclerotic coat. Anteriorly, the choroid coat is gathered into numerous folds which are continuous with the *iris*, a sort of circular curtain situated within the eyeball just behind the cornea. It is the iris which gives the characteristic color to the eyes. The choroid coat is a delicate membrane, freely supplied with blood-vessels, and is deep black in color.

451. The Pupil.—At the center of the iris is a small,

circular opening called the *pupil* of the eye, through which the rays of light are admitted to the interior of the eye. This opening is capable of being slightly increased or diminished in size, thus controlling the amount of light admitted through it.

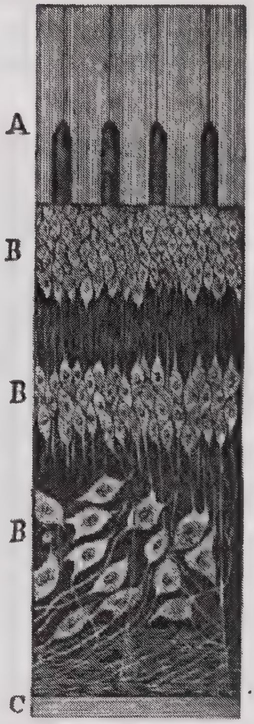

FIG. 167.—STRUCTURE OF THE RETINA.
A.—Layer of rods and cones.
B, B, B.—Distinct layers of nerve cells.
C.—Fibers of the optic nerve.

452. The Retina.—The internal coat of the eyeball is called the *retina.* This is the most delicate and most complex of the three coats. In this membrane are distributed, in a very complex manner, the terminal filaments of the optic nerve, the special nerve of sight. Here the sensations of light are produced. Any irritation of the optic nerve will produce only sensations of light. The sensation of pain, following a blow upon the eye, is not felt in the optic nerve, but in other nerves of general sensation which are distributed to the eyeball.

453. Within the eyeball are situated three different translucent substances: the *aqueous humor*, the *crystalline lens*, and the *vitreous humor*.

The aqueous humor is a thin, watery liquid. It is situated within the space between the cornea and the crystalline lens. This space is called the *anterior chamber* of the eye, and is quite small, containing but a minute quantity of fluid.

The crystalline lens is a structure situated just posterior to the iris and the anterior chamber. It is of a somewhat solid consistency and is enveloped by a thin membrane called the *capsule* of the lens.

The crystalline lens is perfectly transparent, and is double convex in shape. Just in front of it is hung

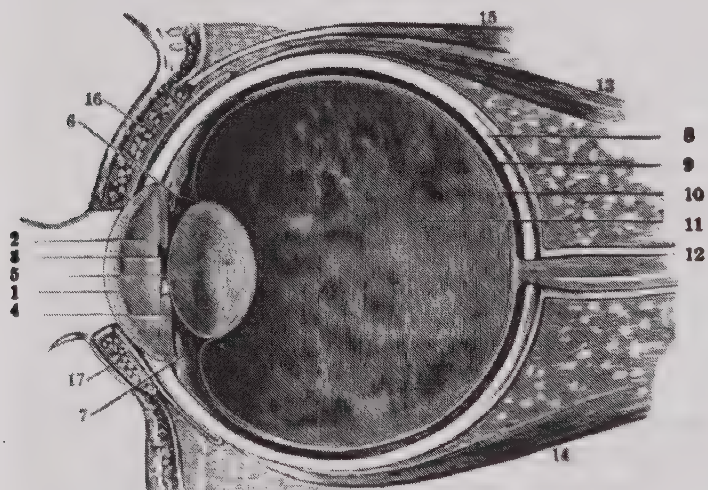

FIG. 168.—VERTICAL SECTION OF THE EYEBALL.

1.—Cornea.
2.—Aqueous humor.
3.—Pupil.
4.—Iris.
5.—Crystalline lens.
6.—Ciliary processes.
7.—Canal around the lens.
8.—Sclerotic coat.
9.—Choroid coat.
10.—Retina.
11.—Vitreous humor.
12.—Optic nerve.
13, 14, 15.—Muscles of the eyeball and eyelid.
16.—Upper eyelid.
17.—Lower eyelid.

the iris, which, by means of the pupil, regulates the amount of light that passes through the lens into the interior of the eye.

Just back of the crystalline lens is a large cavity called the posterior chamber, which contains the *vitreous humor* of the eye. This humor is a translucent, jelly-like substance, and fills the entire cavity of the eyeball back of the crystalline lens.

454. The Optic Nerve.— The special nerve of sight is the *optic nerve.* Arising from the brain, this nerve enters the orbital cavity and pierces the eyeball at its posterior part. Its terminal fibers are distributed and end in a peculiar, complex manner in the retina.

455. Outside of the Eyeball.—The *muscles* of the eyeball are small muscles attached to the sclerotic coat, about its circumference. There are six of these muscles to each eye, and their contraction moves the eyeball in various directions, upward, downward, outward, inward, obliquely.

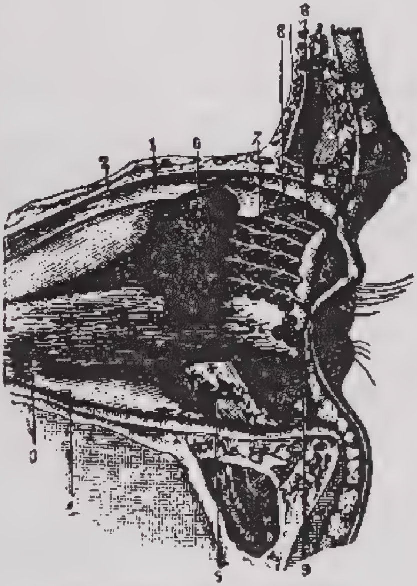

FIG. 169.—SECTION OF THE EYE.
1, 2, 3, 4, 5.—Muscles of the eyeball.
6, 7, 8, 9.—Lacrymal gland, with its ducts.

The *eyelids* are two small movable curtains which serve as a protection to the anterior portion of the eyeball. Lining them is a delicate mucous membrane, called the *conjunctiva*, which is reflected so as to cover the anterior surface of the eyeball. This membrane is very sensitive, and becomes congested by the striking of any foreign particles against it.

456. The Tears.—Just at the outer part of the roof of the orbital cavity is situated a small gland called the *lachrymal gland.* The function of this gland is to secrete a watery fluid, the tears, which, passing

through a small duct, are poured upon the surface of the eye and serve to keep it moist and prevent friction between it and the eyelids. This fluid is being constantly supplied to the surface of the eye, and is drained from it by means of two minute ducts, or tubes, called *lachrymal tubes*, which open at the inner angle of the eyelids. These tubes open into a larger tube, the *nasal duct*, which communicates with the nasal cavity. If the tears are secreted faster than they can be carried off by these ducts, as in the act of weeping, they flow over the eyelids upon the cheeks.

457. **Vision.**—The eyeball in its action may be said to be a complex optical instrument. Into it are admitted rays of light, and within it is produced the image of the object or objects from which these rays emanate or are reflected.

The sensation of light is produced in the retina, by a peculiar stimulus applied to the terminal filaments of the optic nerve, which are here distributed. Just as sound is produced by undulatory waves produced in the air, so light is said to be produced by such waves or vibrations produced in a peculiar medium called the *ether*, which pervades all space. These vibrations in the ether are incomprehensible in their frequency, and it is supposed that different colors are produced by greater or less numbers of vibrations. Thus red is said to be the result of about 392 millions of vibrations per second. These vibrations in the ether, impinging upon the retina, produce there a peculiar stimulus, which, conducted to the brain by the optic nerve, is appreciated as light.

458. **The Image.**—The eye is much smaller than many objects which we look at, and which produce an

image in it. To allow an image to be formed upon the retina, the rays of light from the object must be collected and thrown upon it. This is done by *refraction.* When a ray of light passes through the air, or through any medium which is transparent and has the same density throughout, it moves in a perfectly straight line. If, however, the ray of light strikes a rarer or denser medium it is turned out of its course. This turning of the ray of light from its course is called refraction. In Fig. 170, a b represents a transparent medium; c d and e f are two rays of light passing through this medium in a straight line, the medium being of the same density as the surrounding medium. If, however, the medium a b is denser or rarer than the surrounding medium the rays of light will be thrown from their course; thus the ray e f, for example, will take the course e h if it is denser, or the course e g if it is rarer. Now a ray of light, in order to reach the retina, must pass through four different transparent media. These are the cornea, the aqueous humor, the crystalline lens, and the vitreous humor. All these, and especially the crystalline lens, serve to converge the rays of light into a small space upon the retina, and within this small space the image is formed. This image is well defined, and is in all cases an inverted one. In spite of this inversion, however, the image is appreciated as rep-

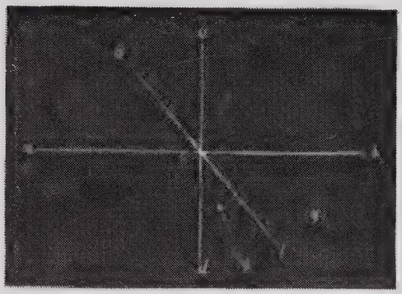

FIG. 170.—REFRACTION

resenting the true position of the object. (Fig. 171.)

459. Faulty Vision.— If we wish to produce an image upon a screen we must have the screen at exactly the proper distance from the lens through which the rays of light pass. If this screen is too near or too far away, the image formed is indistinct in its outline. In the eye the retina acts as a screen and the crystalline lens as the lens. In the normal eye, that is, an eye in which vision is perfect, the retina is

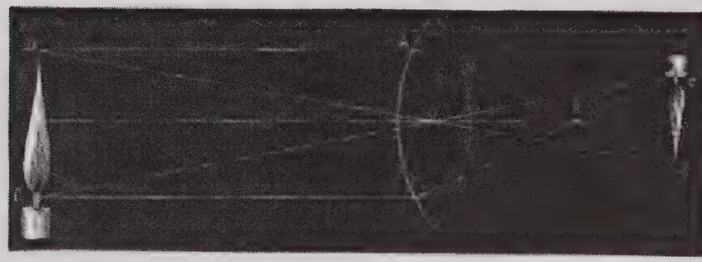

FIG. 171.—FORMATION OF AN IMAGE ON THE RETINA.
A, B, O.—Represents the crystalline lens and
D, E.—The object.
The white lines represent the rays of light passing through the lens and their refraction, producing upon the retina the image d e.

placed at exactly the proper distance from the lens. But in some people the eyeball is longer from before backward than it should be, and hence the retina is too far from the lens. In such cases near objects can be seen, but distant objects cannot, and a form of faulty vision called *near-sightedness* is the result. Again, in some, the eyeball is shorter than it should be and the retina is brought too near to the lens. In these cases distant objects are easily seen, but near objects are not, and a condition called *far-sightedness* is the result. (Fig. 172.)

Faulty vision often occurs in the aged as a result of a hardening of the crystalline lens, and may occur in younger persons from a variety of causes.

Cases of faulty vision can, as a rule, be remedied to a great extent by the wearing of glasses, the shape of which should vary according to the trouble which they are intended to mitigate.

A.—NORMAL EYE.
X.—Correct place for image or focus.

B.—NEAR SIGHT.
X.—Where image is formed.

C.—FAR SIGHT.
X.—Where image is formed.

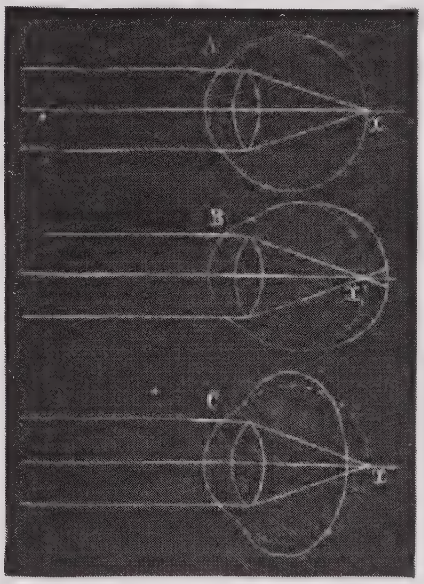

FIG. 172.—DIAGRAM TO ILLUSTRATE NEAR-SIGHTEDNESS AND FAR-SIGHTEDNESS.

460. Color-Blindness. — Some persons are afflicted with a kind of faulty vision called *color-blindness*. The normal eye is so constructed that its possessor is able to distinguish between different colors. In persons afflicted with color-blindness, this power is absent, especially the distinguishing between red and green. Occasionally there are cases in which there is an

inability to appreciate any colors, all colors appearing simply as shades.

461. Accommodation.—The crystalline lens of the eye is supplied with a small muscle, which by its action can cause the lens to become thicker or thinner. The eye is thus enabled to adapt itself to near and to far objects. This is called *accommodation*, and any interference with it hinders correct vision. (Fig. 173.)

462. How the Eyes May be Injured.—The kind and amount of light has much to do with good eyesight. One should not read or write in the twilight, nor by poor and flickering artificial light. The eyes are in this way easily strained. Neither should one read by a light which shines directly in the eyes, but should turn his back to the light so that it will shine over the shoulder and upon the book or paper. Another source of eye strain is the practice of reading in railway cars. The irregular oscillating movements cause the book or paper to be held too near the eyes, thus keeping these delicate organs on a constant strain.

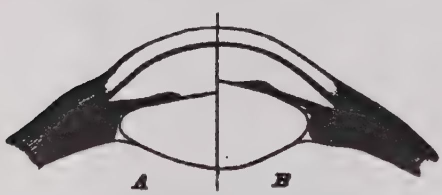

FIG. 173.—ACCOMMODATION.
A.—Lens adjusted for near objects.
B.—Lens adjusted for far objects.

Eye washes and salves should not be used unless advised by a physician. They are often the cause of serious irritation and inflammation of the eyes.

463. The use of tobacco is a frequent cause of color-blindness. The irritating action of tobacco smoke causes haziness, and sometimes produces a total loss of sight. Tobacco sometimes produces a wasting

away of the optic nerve, and this leads, sooner or later, to partial or total blindness. This disease of the eye is called *tobacco-amaurosis*, and the peculiar symptoms which accompany it very clearly indicate tobacco as its principal cause.

464. The use of alcoholic drinks very frequently produces painful and serious diseases of the eyes. The bloodshot and inflamed condition of the eye-balls in confirmed alcohol drinkers is evidence that the eyes are very easily affected by this poison. Nearly all such persons are troubled, sooner or later, with disordered eyesight. Drinkers of alcohol find it difficult to recover from diseases of the eye, especially if these diseases be of an inflammatory nature.

The constant congestion which alcohol produces acts as a prevention to recovery, often hastening and rendering serious what might otherwise have been a slight and temporary disease. Acute eyesight is absent in persons who indulge in alcohol, and the eyes of these persons easily tire with moderate work. Color-blindness and haziness of vision are of common occurrence among them, and indeed it is rarely that this class of people have normal, healthy eyes and eyesight.

465. **Practical Rules.**—The following rules, which were formulated in a lecture given at the Franklin Institute of Philadelphia, are worthy of careful study. If followed they will do much towards the preservation of healthy eyes and good eyesight.

1. Avoid sudden changes from dark to brilliant light.

2. Avoid the use of stimulants and drugs which affect the nervous system.

3. Avoid reading when lying down and when mentally or physically exhausted.

4. When the eyes feel tired rest them by looking at objects at a long distance.

5. Pay special attention to the hygiene of the body, for that which tends to promote the general health acts beneficially upon the eye.

6. Up to forty years of age bathe the eyes twice daily with cold water.

7. After fifty bathe the eyes morning and evening with water so hot that you wonder how you stand it; follow this with cold water, that will make them glow with warmth.

8. Old persons should avoid reading much by artificial light, be guarded as to diet, and avoid sitting up late at night.

9. Do not depend on your own judgment in selecting spectacles.

If foreign bodies of any kind enter the eye they should be at once removed. Failure to do this is likely to produce serious inflammation.*

* For directions as to removing foreign bodies from the eyes, see § 583.

PART II.

THE CARE OF THE BODY AND THE PRESERVATION OF HEALTH.

SPECIAL CHAPTERS ON PRACTICAL HYGIENE.

XLIX.—PRACTICAL HYGIENE.

466. Hygeia.— Among the beneficent deities who were held in loving esteem by the ancient Greeks none were more worthy of regard than Æsculapius, the first of all physicians, and his daughter Hygeia, the goddess of health. While the former healed the sick and taught men how to concoct medicines for the cure of all ailments, the latter, by her very presence, prevented all forms of disease and made all medicines unnecessary. And so it was said that those who dwelt with Hygeia and obeyed her teachings were never in need of a physician; for no baneful influence of air or water or unseen being had any power to touch or harm them. This story was not altogether a product of the imagination; in its essential features it expresses a great truth which is as applicable to us in our own times as it was in those ancient days to the people who gave it more literal credence.

467. The Science of Health.— From the goddess Hygeia we derive the name of one of the most practical of all sciences, *hygiene*, the science of preserving health. The laws of hygiene are not difficult to obey, and those who observe them carefully and judiciously will be most amply rewarded. These laws have been formulated, not arbitrarily nor by guess-work, but upon facts and principles derived from the scientific and practical study of the human body, its parts and organs and their various functions. A knowledge of anatomy and physiology is of value to us only as it

enables us the better to comprehend the rules of hygiene, thereby being incited to their more careful observance. The physician studies anatomy and physiology, even in their minutest details, in order that, like Æsculapius, he may wisely combat disease and heal the sick of their ailments. Students at school acquire a general knowledge of the same subjects, but for a very different purpose. They learn the leading facts about the structure of the body and the functions of its parts and organs in order that they may have intelligent ideas concerning the preservation of their health and the proper development of their strength. The physician is a disciple of Æsculapius; the student—and indeed everybody else—ought to be a follower of Hygeia.

468. **Laws of Hygiene.**—What do you suppose was the character of the rules which Hygeia prescribed? They were the same that are now popularly known as the *laws of hygiene.* They were nothing more nor less than the laws of nature as applied to the care of one's body. They can all be summed up under a few brief generalizations which every individual can understand and in most cases observe:

Keep every part of the body clean.

Eat wholesome food.

Breathe pure air.

Avoid excesses.

Keep your body and mind active.

These five general rules include the whole science of hygiene; indeed, if the first and last were wisely and rigidly observed there would be no need for more, for they include the other three. But in order that no one shall be ignorant of the manner in which to observe

them, it is necessary to explain them somewhat in detail and to indicate a number of subsidiary rules. This shall be briefly done in the chapters that are to follow.

469. Beneficial Results of a Knowledge of Hygienic Laws.— Sound health, a vigorous constitution, and a well formed body are desired by every person. Indeed, it is the intention of nature that the human body should be perfect. Nature provides everything that is essential for life and health; and so, if instead of strength one has feebleness, if instead of health he has disease, it follows that somewhere and at some time the laws of nature have been violated. It is the object of this science of hygiene to teach people how to observe nature's laws. For wherever men are most ignorant of the laws upon which hygienic principles are based, there disease and death are common; but wherever these principles are known and most generally observed, there sickness becomes rare and the rate of mortality is diminished. Two hundred years ago in London the average yearly mortality was 80 for every 1,000 inhabitants; now it is but little more than one fourth as great. The same results have been shown in nearly all parts of the civilized world, and these results have been produced by the increased study and application of the rules of hygiene.

In the following extract from an address given before the American Public Health Association, Dr. Stephen Smith makes a plain and truthful statement concerning the value of such study. He says:

"Were a well digested system of education in hygienic matters, which so vitally concerns the well-being of every person, adopted and put into practice

with anything like the vigor with which we insist upon the study of the common and useful branches, like geography, arithmetic, and grammar, and the uncommon and ornamental branches, as French, music, etc., within one generation the whole mass of people would be so enlightened on the subjects relating to the hygiene of everyday life that our average longevity would be immeasurably increased."

470. Health.—As generally used, the word health signifies a comfortable state of the body—an absence of pain or discomfort. Strictly speaking, however, health implies a perfection of all the functions of the body. A body which has health is fully developed, and all its organs and sets of organs are sound and in perfect working order. A vigorous body being so precious a thing and so earnestly desired by everybody, we should naturally suppose that the thoughts and energies of mankind would be chiefly directed towards acquiring and maintaining physical perfection. It is a lamentable fact, however, that but few people have perfect health and that the majority of the world's inhabitants live in daily disregard of nature's most salutary laws.*

To some persons, no doubt, a state of perfect health is impossible on account of hereditary influences, but

* "Ill health and premature death are the rule rather than the exception in average human life, and are penalties paid for the violation of natural laws, which, as they relate to health, are sanitary laws. Obedience to many of the most important natural laws is intuitive and unconscious. A knowledge of others is now possible for the majority of civilized people, and therefore their violation is inexcusable in proportion to education, information, and civilization."

if these persons would conscientiously observe and apply the principles of hygiene, many of them could finally attain to a condition which very closely approaches that of health.

Although health may sometimes be acquired even after one has been temporarily deprived of it, it is, nevertheless, a condition which should be preserved with the greatest of care.

471. Disease.—But modern hygiene does not stop with the formulation of laws for the preservation of health. It goes much farther, and when these laws have been disregarded and broken, it assumes the rôle of the physician and seeks to determine the cause of disease and to point out the means of a return to health and physical vigor. Disease may be defined as a condition of the body in which there exists pronounced disturbances in one or more of the life processes. It may be caused either by the violation of hygienic laws, or by the admission of certain poisons into the system. The latter are sometimes taken voluntarily and produce destructive effects upon the tissues with which they come in contact. Sometimes they exist in the form of invisible minute organisms of vegetable or animal origin, which exist unseen in the air, the water, or the food, and which no law of hygiene will enable us wholly to avoid. These micro-organisms are often spoken of as germs, and under favorable conditions they thrive and rapidly multiply.

472. Disease Germs.—Disease is specially liable to attack an unhealthy body—one which has been enfeebled by unhygienic surroundings or by the want of proper nutrition and care. Disease germs exist in

large numbers in unhygienic localities. These germs gain entrance into the body in various ways, and if they there find suitable conditions for their growth, disease of a more or less dangerous character is sure to result.

An unhealthy body usually affords fertile ground for the growth of such germs; but a sound, vigorous system resists their growth, and even if it should be attacked by disease, it is able to combat it much more successfully. The science of hygiene, by showing how this soundness of body may be secured and maintained, also helps us to guard against those insidious and unseen causes of disease which are so greatly to be dreaded.

473. Specific Hygienic Topics.—The application of the principles of hygiene involves attention to many particulars. Let us summarize the most important of these particulars:

1. The personal care which one must have for his health. This includes attention to food, drink, clothing, exercise, habits of life, and personal cleanliness.

2. The environments which are likely to affect one's physical condition. This includes the location of one's dwelling, its drainage and ventilation, the climate, and other extraneous influences.

3. The means of restoring lost vigor or of combating disease. Under this head may be considered the care of the sick, the avoidance of contagious diseases, the methods of rendering aid to the injured or of wisely meeting unexpected emergencies.

Of each of these topics we shall have something to say in the chapters that follow.

L.—DIET.

474. Nature abundantly provides foods for man which are suitable to his wants under all conditions. Health and long life depend very much upon the adaptation of the food to the actual needs of the body. The quality and quantity of food required differ according to the circumstances of individuals, their age, habits, and surroundings.

Local conditions, as climate, etc., have decided influence upon diet. The inhabitants of the arctic regions demand great quantities of animal food; those of the torrid zones thrive best on an exclusively vegetable diet; and those living in temperate climates require both animal and vegetable foods. It is found that the most suitable diet for man under ordinary circumstances is a mixed one, consisting approximately of three fourths vegetable food and one fourth animal food. An excess of animal food tends to overtax the excretory organs, and is therefore harmful.*

475. Rules for Eating.—Adhere to a rational diet. Choose that kind of food which experience has shown to be best adapted to your needs. Eat those articles

* While fruit gives but little toward the nutriment of the body, it contributes materially toward keeping it in health. Bender found that fruit, while on the tree and when stored in the house, gives off a great deal of carbonic acid; so that it is not well for persons to sleep in a room where fruit is kept in large quantity. Uffelmann praises the fruit diet in chronic indigestion, scurvy, and hepatic affections; and the exclusive diet of grapes was highly commended by Niemeyer in certain unhealthy conditions.

which common sense tells you are of the greatest nutritive value, and which are at the same time agreeable to the taste and unobjectionable to the stomach.

Take food at regular intervals. The stomach, as well as other organs, requires a certain amount of rest. The habit of eating between meals and at unseasonable hours overtaxes the stomach and cannot but weaken the digestive powers.

No general rule can be given as to the length of time which should elapse between meals. Three meals a day, from four to six hours apart, appear to be the most conducive to health.

As a general rule the heaviest meal should not be eaten until after the day's work is done. Give a reason why this is true.

After the night's rest, no active labor or business should be engaged in until a good breakfast has been eaten. The system is thus fortified and strengthened for the duties of the day.

To most persons a light lunch in the middle of the day, composed of farinaceous foods, vegetables and fruits, is far better than a heavy meal with meats.

Eat slowly, and masticate the food thoroughly. Good digestion depends to a great extent upon proper mastication. Why?

Besides the above rules the following hints are well worthy of attention:

It is not advisable to eat a hearty meal when one is very tired, cold, overheated, or in mental trouble.

After severe exercise it is well to rest in an easy position for half an hour before eating.

Abstain from work for at least half an hour after eating a hearty meal.

The organs, both secretory and excretory, are best kept in good condition by drinking freely of water between meals. Liquids should not be taken excessively during meals. All forms of alcoholic beverages should be strictly avoided. Even small quantities are likely to prolong and hinder digestion.

476. Agreeable and Disagreeable Foods. — Food must not only contain the principles of nutrition, it must be in a form which makes it easily capable of being disintegrated and dissolved in the alimentary canal. A substance eaten may be nutritious in its nature and yet very indigestible, and therefore not a good food. On the other hand, a substance which is easily digested may contain little or no nutriment, and hence be of but slight value. Habit has much to do with digestion. Poor people who are accustomed all their lives to the plainest fare are unable to eat rich foods, but find them distasteful and hard to digest. The diet which agrees best with the Eskimos of Alaska would be offensive and injurious to the natives of Cuba. In most cases, the food which we like best agrees with us, and is the most easily digested. Tastes differ, and yet for most people there are certain articles which are always acceptable and wholesome.

477. Cooking—Meats.—Most foods are improved by cooking, being so changed by the action of the heat as to become not only more appetizing but more digestible. Meat, to be acceptable diet for human beings, must be cooked. Broiled meat agrees best with most stomachs. To broil meat properly, the fire should be a brisk one, so that the albumen on the surface of the broiling piece shall be quickly coagulated; the juices are thus prevented from escaping, and the meat is

made more tender and palatable. Meat to be boiled should, for the same reason, be plunged at once into boiling water. But if soup is to be made, the meat should be placed in cold water and gradually heated to the boiling point; by this means the savory and nutritious juices are extracted to become the chief constituents of the soup. Meat to be roasted should be at once subjected to a strong heat, in order to retain these juices as in broiling. Fried meats are the least wholesome and the hardest to digest, being so imbued with the heated fat as to resist the action of the gastric juice. The smoking of beef renders it more difficult to digest; and, as a general rule, the salting of meat has a tendency to retard the action of the digestive fluids. Experiments have shown that while fresh boiled beef with a little salt is digested in less than three hours, old salted beef cooked in the same way requires more than four hours for digestion. (See § 165.)

478. Farinaceous Foods and Fruits. — Generally speaking, the most digestible of all farinaceous foods is light, well-made wheaten bread from twelve to twenty-four hours out of the oven. Next to wheat flour, rye makes the best and most wholesome bread. Oatmeal, barley, and Indian corn are also largely used, and if properly prepared are very nutritious. In many countries rice is the principal article of food; it affords but little blood-making material, and hence when used alone large quantities are necessary to support life; but when used with other nutritious foods it is a valuable article of diet, unstimulating and easily digested. Peas, beans, and other leguminous foods afford much nutriment, but are hard to digest. Potatoes and other foods composed largely of starch are highly nutritious

when so cooked as to reduce them to a pulp and thoroughly soften and disintegrate the starch grains. Baked potatoes are, for this reason, more readily digested than boiled potatoes. The same rule applies to fruits. Baked or roasted apples are more easily digested than raw apples.

479. Bread-Making.—The best bread is made from wheat flour. Good flour contains a variety of nutritious substances. On the average, in every hundred pounds of such flour we may find 72 pounds of starch, 7½ pounds of gluten, 5¼ pounds of sugar, and 12 pounds of water. The remainder consists of phosphates of lime and magnesia, alkaline sulphates, gum, and common salt in various proportions. There are many methods of baking bread. *Unleavened bread* is made by working into the dough a considerable quantity of air, which remains there in the form of bubbles. When the dough is placed in the oven the heat causes these bubbles to expand, and they, pushing the dough apart, cause the bread to become light. *Yeast bread* is made by mixing a small quantity of yeast with the dough during the process of kneading, and then allowing the mixture to stand for some hours in a moderately warm place. The yeast produces in the sugar of the flour a fermentation by which it is changed into alcohol and carbonic acid. The carbonic acid in the form of small bubbles is entangled and held in the dough by the gluten of the flour. As the dough becomes warmer these gaseous bubbles expand and cause the whole mass to become inflated, or to "rise." It is then placed in the hot oven and kept there until the baking is complete. The heat causes the alcohol and carbonic acid gas to pass through the dough

and escape in the oven. It also changes the starch upon the surface of the loaf to dextrine, hardening it into a brittle layer; this is the crust. It solidifies the gluten, which at the same time acquires an agreeable flavor. It causes the starch grains to become swollen and fused together, and these retain within their substance a part of the water which was mingled with the flour. Bread, therefore, always weighs more than the flour of which it is made. On account of the multitude of gaseous bubbles which are diffused throughout the dough during the process of "rising," it has a spongy appearance, containing a great number of little cavities distributed more or less regularly through its substance. This is what makes the bread light. Light bread is more easily masticated and more readily mixed with the digestive fluids; it is, therefore, for most people, the most nutritious and healthful of all breads. Another and very common method of making light bread is by the use of baking powder instead of yeast. Baking powder is composed of certain chemical substances which when moistened and heated are decomposed, thus generating carbonic acid gas. The gaseous bubbles are diffused throughout the dough precisely in the same manner as in the making of yeast bread.

480. The Effect of Cooking. — Why does cooking render a food substance more digestible?

What effect does good cooking usually have upon the palatableness of a food? Give one reason why.

Why is roast beef more wholesome than fried beef?

Why is broiled meat so palatable and healthful?

Why is wheat bread more wholesome and nutritious than any other bread ?

Why is light bread better than bread made simply of flour and water?

Why does bread weigh more than the flour of which it is made?

Is there any alcohol in yeast bread? Why not?

What becomes of the carbonic acid which makes the bread light?

The cooking of food, to be beneficial, must be properly done. Bad cookery not only renders food unpalatable, but is frequently the cause of disease. The fact should always be borne in mind that the object of cooking is to prepare the food for digestion—to make it palatable and agreeable, and to render it more easily amenable to the digestive processes. Foods prepared in such a way as to hinder the action of the saliva, the gastric juice, or the intestinal fluids—no matter how they may please the taste—are unfit to be eaten. Ignorance of the proper methods of cookery is the cause of much disease.

481. Injurious Foods.—Not only are poorly cooked foods injurious, there are certain classes of so-called foods which should always be avoided. Decayed fruits, mouldy bread, sour milk, meat that has begun to decompose — these if eaten are liable to produce disease. The milk of unhealthy cows frequently contains germs which communicate diseases to those who partake of it. Any noxious germs contained in milk may be destroyed by boiling it. If this precaution were oftener taken, much of the sickness prevalent among children might be avoided. Pork is often infested with minute parasites called *trichinæ*, which, when taken into the stomach, increase rapidly in numbers and penetrate to various parts of the body, caus-

ing severe illness and death. Pork chops, ham, and bacon should, therefore, always be thoroughly cooked before being eaten.

482. Scale of Digestibility. — The following comparative scale of digestibility is given by M. Navarre, a distinguished French physiologist:

1. *Aliments always easily digested.*—Coffee and milk well sweetened; boiled brains; soft boiled eggs; white meat of broiled fowl without skin or fat; the following fish, boiled, broiled with butter, or fried in crumbs—trout, sole, perch, smelt, gudgeon, French sardine; all green vegetables, boiled and then cooked in butter or with a white sauce; sweet milk compounds; very sweet side dishes; very sweet and thoroughly cooked jams; sweetened rice; purée of potatoes; dry biscuits; calf sweetbreads, not larded; well cooked bread; very sweet fresh cream.

2. *Aliments tolerated less easily.*—Asparagus out of season; rice and butter; roasted veal; roast beef; roast pigeon; wild duck; pot-pie; smoked ham; broiled mutton kidney; partridge, quail, snipe, turbot, salmon, ray, oysters, various shell-fish, fresh cod; potatoes with jackets; Swiss cheese and others which are fresh; boiled calves' feet; sheep's feet; tripe; new potatoes cooked in butter; and, in general, all sauces except the white.

3. *Aliments always badly supported.*—Fat soups; mutton (leg and chops); all larded meats; all black meats; all game except that mentioned above; pork and sausages and kindred meats; mackerel, mullet, lobster, crabs, sardines in oil, salt codfish; fried potatoes, and, in general, all fried dishes; raw side-dishes, raw salads, and all dry vegetables, even in purées; and made cheeses.

483. The following table gives the average length of time which is required for the complete digestion of some of the more common articles of food:

TABLE SHOWING THE TIME REQUIRED FOR THE STOMACH DIGESTION OF VARIOUS ARTICLES OF FOOD.

ARTICLE OF DIET.	MODE OF PREPARATION.	H. M.
Apples, sweet, mellow	Raw	1:30
Apples, sour, mellow	Raw	2:00
Apples, sour, hard	Raw	2:50
Bass, striped, fresh	Broiled	3:00
Beans	Boiled	2:30
Beef, fresh, lean, rare	Roasted	3:00
Beefsteak	Broiled	3:00
Beef, fresh, lean, dry	Roasted	3:30
Beef, with salt only	Boiled	3:36
Beef	Fried	4:00
Bread, corn	Baked	3:15
Bread, wheat	Baked	3:30
Cabbage	Raw	2:30
Cabbage	Boiled	4:30
Chicken, full grown	Fricasseed	2:45
Chicken, full grown	Boiled	4:00
Chicken, full grown	Roasted	4:00
Codfish, cured, dry	Boiled	2:00
Eggs	Whipped	1:30
Eggs	Raw	2:00
Eggs	Roasted	2:15
Eggs	Soft Boiled	3:00
Eggs	Hard Boiled	3:30
Eggs	Fried	3:30
Lamb	Broiled	2:30
Milk	Boiled	2:00
Milk	Raw	2:15
Mutton, fresh	Broiled	3.00
Mutton, fresh	Boiled	3:00
Mutton, fresh	Roasted	3:15

ARTICLE OF DIET.	MODE OF PREPARATION.	H. M.
Oysters, fresh	Raw	2:55
Oysters, fresh	Roasted	3:15
Oysters, fresh	Stewed	3:30
Pork, fat and lean	Roasted	5:15
Pork, recently salted	Stewed	3:00
Pork, recently salted	Broiled	3:15
Pork, recently salted	Fried	4:15
Pork, recently salted	Boiled	4:30
Pork, steak	Broiled	3:15
Potatoes	Roasted	2:30
Potatoes	Baked	2:30
Potatoes	Boiled	3:30
Salmon, salted	Boiled	4:00
Trout, fresh	Boiled	1:30
Trout, fresh	Fried	1:30
Turnips	Boiled	3:30
Veal, fresh	Broiled	4:00

LI.—WATER AS A FOOD.

484. Water.— Next to air, water is the substance most necessary to the maintenance of life. The amount of water required for the healthful nutrition of the body is from five to six pints each day. Water for drinking purposes is derived from various sources: by collecting it as it falls as rain; by taking it from streams, or springs, or lakes; by lifting it from wells.

Rain water, if clean, is the purest that can ordinarily be obtained. The first rain that falls collects much soot and dust from the air and from the roof upon which it falls, and should be discarded. The remainder is usually water of excellent quality for

drinking purposes, and especially for cooking, on account of its being soft water.*

Water from streams, if not polluted with refuse, is fairly pure for drinking purposes, especially if the streams be fed by springs. The water from small lakes is also fairly pure, provided they are not stagnant, and are not polluted by refuse or decaying matter along the shores.

Well water and *spring water* are usually quite pure as well as very palatable. Care should be taken that they are not rendered impure by the admission of surface drainage. Well water, or spring water, is rain water which, striking the soil, sinks into the ground until it reaches a stratum of impermeable rock, where it is retained. Hence it is that a considerable area in the neighborhood of a well should be kept clean in order to avoid any possible contamination of the water. Deep well water is much more likely to be pure than water which is taken from shallow wells.†

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*"Ordinarily, rain water that has percolated through the soil for a considerable distance is remarkably pure and wholesome. It soon loses by filtration the impurities it received from the air and the surface on which it fell, though it may take up some of the mineral constituents of the different soils through which it passes. When the quantities of these mineral substances become so great as to give the water a medicinal value, or marked taste, we call it a *mineral water;* but when the inorganic matter does not render the water objectionable to the taste, or too hard, it will probably be found to be purer than that from almost any other source."

†"The impression that spring or well water taken from a rock or ledge has a guaranty of purity is a serious popular error. Water in passing through a deep layer of porous soil or sand undergoes a process of filtration, and purification. Rock, on the contrary, has no power to purify, and its crevices sometimes convey polluted surface drainage long distances into wells or springs."

485. Purification of Water.—Water is seldom found in a perfectly pure state, and good drinking water is not necessarily perfectly pure water. Water to be suitable for drinking purposes should contain no injurious organic impurities, it should be perfectly clear, free from any odor or taste, and, if possible, soft or at most only slightly hard.

FIG. 174.—A DROP OF VERY IMPURE WATER. (Magnified.)

Impurities in water may consist either of solid matters in suspension, or of substances in solution. Water is made turbid by solids in suspension; clear water does not contain these, but may contain bacteria or other micro-organisms. Water which contains much solid matter may be, to a certain extent, purified by *filtration*. In using a filter care should be taken that it is regularly cleaned, for a dirty filter will work more harm than good.*

The best substances through which to filter water

*Other things being equal, the value of a water will probably be about as shown in the following table:

Wholesome:	1. Spring water,	Very palatable.
	2. Deep well water,	
	3. Water from unpolluted streams,	Moderately palatable.
Suspicious:	4. Stored rain water,	
	5. Surface water from cultivated land,	Palatable.
Dangerous:	6. Sewage-polluted river water,	
	7. Shallow well water,	

are sand, animal charcoal, spongy iron, porous stones, and unglazed porcelain.

Filtration, however, has no effect in removing organic impurities, and if water used for drinking purposes is not entirely above suspicion as to its purity, the only safeguard lies in a thorough boiling of it. Boiling destroys all living organisms. Suspected water should be boiled about half an hour before being used.

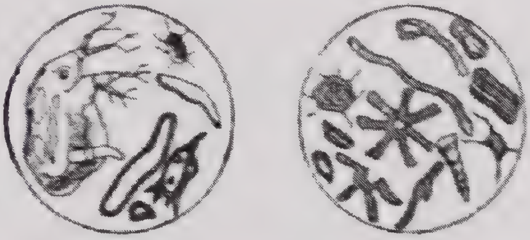

FIG. 175.—ORGANIC IMPURITIES FOUND IN IMPURE WATER.

486. Impure Water and Diseases.—Many forms of disease are directly traceable to the use of impure drinking water. Stomach and intestinal irritation may be caused by suspended or dissolved organic or mineral matters. Tapeworms may be admitted into the system by taking the ova of this parasite into the stomach in drinking water. Dangerous infectious diseases, as typhoid fever, cholera, and malaria, are often caused by drinking water which contains the germs of the disease. Typhoid fever becomes widely spread in this way. It is always a safe rule in times of an epidemic of typhoid fever to boil thoroughly all water that is used.

Ice, unless it is known to be made from pure water, should not be added to drinking water. Freezing does not destroy disease germs, and impure ice is no doubt often a direct cause of disease. Dr. Prudden experimented on the effects of cold upon disease germs, and caused typhoid germs to be frozen solidly in ice

for over three months; at the end of that time it was found that their vitality had not been affected. Thus it is plain that there may be and is much danger of contamination through ice.*

LII.—CLEANLINESS.

487. Cleanliness and Health.—The skin, as has been explained, is a very complex structure, containing numerous nerves, blood vessels, and glands (§ 145). Its functions—regulation of bodily heat, and excretion —are of much importance to the health and welfare of the body. The surface of the skin is constantly casting off worn-out particles of epidermis, and the glands are constantly pouring out sweat and oily matter. The secretions of the glands dry upon the surface of the skin and hold upon it the particles of waste matter and quantities of dust and dirt, thus forming a layer of foreign matter, the existence of which is detrimental to the health in several ways. Cleanliness of the skin is, therefore, of much importance.†

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* The free internal use of water is recommended to all. It tends to increase the secretions of the skin and of the bile, saliva, gastric juice, and pancreatic juice. The too free use of water at meal time is apt to be more or less injurious, as it dilutes the digestive juices and is thus likely to cause indigestion. Between meals, however, the free use of water will be of much benefit to the system.

† Hufeland, in his "Art of Prolonging Life," says, "I regard cleanliness and cultivation of the skin as the chief means for the prolongation of life. Cleanliness removes everything which our system has separated as useless and injurious, as well as everything which has attached itself to our bodies from without. The culti-

488. What is perspiration? Why is perspiration necessary to health? If the process of perspiration be hindered, what will be the result? What other organs will be overtaxed? From your answers to these questions deduce a reason why the skin should always be kept clean.

489. Dirt upon the surface of the skin is a frequent cause of skin diseases. It affords a medium favorable for the growth of bacteria or micro-organisms, which, besides producing local diseases of the skin, may affect the whole body. Skin diseases and affections are, to say the least, greatly aggravated by the presence of dirt.

490. **Bathing.**—The only way in which the skin can be kept in a clean and healthy condition is by frequent bathing. Besides serving to remove unhealthy accumulations of dirt and waste matter from the skin, baths properly taken act as a general invigorator to the body.* They quicken the circulation, tone up the skin,

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vation of the skin is an essential part of this process, and consists in such treatment from childhood to old age as will render it active and open."

* The religious observances of all sects of antiquity commanded washing and bathing in some form among their ceremonials.

The Egyptian priests were required to wash their bodies three times a day whenever they prepared for great sacrifices.

The Jewish ordinances contain numerous commandments for bathing and purification.

The Greek priests washed themselves twice every day and night, in order to be fitted for their sacred duties.

The pious Turk regards it as imperative to wash his face and hands and arms and neck before he invokes Allah.

The Brahmin makes his ablutions three times a day, and the rich and poor alike journey to the shores of the Ganges to purify themselves in the sacred waters.

and produce a sense of well-being. Bathing, in order to produce the most good, should be indulged in frequently, and should be thorough,—that is, the body should be thoroughly washed all over. A bath taken every day would not be too much, and a thorough bath at least once a week is essential to the proper action of the various organs As to whether a bath should be taken in hot or in cold water depends upon circumstances and upon one's inclination. Many persons take cold baths at all seasons of the year and derive invigorating effects from them.*

491. The Cold Bath, while not being so valuable as the hot for cleansing purposes, is more stimulating and strengthening. It serves as an excellent tonic to the whole body, and causes an increase in its various functions. If the cold bath be followed by a brisk rubbing with a rough towel, as it should be, it will rarely produce any chilly or unpleasant sensations. Probably the most suitable time for taking a cold bath is in the morning after rising. A cold bath for one who is strong is a luxury. It produces a most comfortable condition of the skin, and causes it to be healthy and rosy. It accelerates the circulation, increases the number and depth of the respirations, and acts as a tonic to the nervous system. The cold bath should not be a prolonged one, especially if the water be very cold or the person not in the best condition. From three to five minutes is generally sufficient.

For aged persons and those in weak condition, the

*A cold bath is that in which the temperature of the water is from 30° to 60° F.; a cool bath is from 60° to 75° F.; a temperate bath from 75° to 85° F.; a tepid bath from 85° to 92° F.; a warm bath from 92° to 98° F.; and a hot bath from 98° to 112° F.

cold bath is not always advisable, and if indulged in at all, great care should be taken to avoid getting overchilled.*

492. Salt Water Baths. — Outdoor bathing and salt water bathing are to be considered as cold baths. They have a great value because they combine exercise and bathing in one. Care should be taken that this form of bathing is not indulged in to excess. If it is, evil effects are almost certain to follow. One should never indulge in outdoor bathing until an hour or more after eating, and, when leaving the bath, the body should be rubbed dry and the clothing be immediately put on. If a chill follow the bathing, the skin should be briskly rubbed, then dry clothing be put on,

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* "In Alaska the method ot taking a bath is somewhat heroic. Every trading-post has a bath house, and the people are supposed to avail themselves of its privileges once a week. A person accustomed to living in a milder climate would have a good deal of hesitancy about undressing in one of these places, as the temperature is always below zero. In an inner room an arch of stones is built so that a fire made beneath can penetrate. A trap-door in the roof answers for a chimney. After the stones have become thoroughly heated and the smoke has passed out, all the coals are removed and the trap-door closed. In this room stands a cask of warm water and another that is ice-cold. When the bather enters he pours hot water on the stones until the room is filled with steam; then, taking a seat on a bench, he waits till the perspiration streams from every pore in his body. Next he takes a bunch of dried twigs and leaves, prepared for the purpose, with which he scrubs himself till all the impurities have been removed from the skin, following this with a wash-off in warm water and soap. He concludes his bath by dashing a bucket of ice-cold water over his body, and then rushing to the dressing-room, where, with his teeth chattering, and shivering in every limb, he resumes his clothes."

and brisk exercise taken until a comfortable degree of warmth is restored.

Salt water bathing is especially valuable as a tonic bath, and in many instances it is much more invigorating than a bath in fresh water.

493. Cautions.—Care should be taken never to bathe in cold water immediately after severe exercise, nor when the body is in a heated condition and covered with perspiration. The sudden application of cold water under such circumstances is sure to produce unpleasant results. Cold baths should not be taken soon after eating and while digestion is going on, nor is it advisable that they be taken in a cold room.

As a rule, persons who regularly bathe in cold water are much less liable to take cold than those who do not. Bathing the head and face with cold water is often very refreshing in cases of headache or excessive mental strain.

494. The Warm Bath is more cleansing than the cold, and to many persons much more comfortable. It is better to take it at night before going to bed, for, on account of its relaxing effect, colds are easily contracted if the body be exposed to the open air. After severe physical labor, a hot bath will often produce a sense of rest and comfort. One can safely stay in a warm bath longer than in a cold one. but five or ten minutes is usually long enough.*

* The skin should assist in the work of elimination and protection. Cold sponge baths to the chest have a salutary effect on the lungs, but must be immediately followed by friction with a coarse towel. A hot sponge bath should be taken at night, and the body should be vigorously rubbed afterward. If there is a tendency to "catching cold," the body may be well rubbed with some nutritive oil, as olive oil.

495. The Hair and Nails.—Cleanliness of the hair and nails is essential to their growth and health, as well as to personal beauty. The scalp should be washed frequently and rubbed with a soft brush to remove particles of scurf. Hair tonics and hair pomades, as a rule, are of no advantage, many of them producing harmful results.

If the hair is dry and harsh, the use of a small quantity of vaseline well rubbed into the scalp is often beneficial. Strong soap should not be used in washing either the scalp or the skin. Such soap contains much alkali, and tends to remove the oily secretion from the skin or scalp, thus causing it to become harsh and rough. A mild soap should be used, and never more than is necessary for cleanliness.

LIII.—THE CLOTHING.

496. Kinds of Clothing.—Clothing is manufactured of wool, fur, silk, cotton, or linen, each of which has special qualities which adapt it to use for special purposes or under special circumstances. Woolen goods, flannels, and furs, are materials which will not readily conduct the heat from the body. They should be worn next to the skin, especially in cold weather and in variable climates. The non-conducting properties of woolen goods are due mainly to the fibers being loosely woven, this also aiding in the process of evaporation.

Silk goods are also warm, and are not so likely to irritate the skin as those of wool.

Cotton and linen materials are good conductors of

heat, and hence are adapted for use in warm weather. The wearing of them next to the skin is often not beneficial, light woolens being preferable even in hot weather.

Clothing of light colors, as white or gray, is cooler than dark or black clothing, especially in the warm season.

497. Hygienic Clothing.— Proper clothing is of much importance from a hygienic point of view. Good judgment should be exercised as to what and how much to wear. Much care should be observed in this matter, especially in changeable climates, where there is always a certain amount of danger from colds, pneumonia, and various lung diseases. If some parts of the body are more heated than others by overdressing or in any other way, an excessive flow of blood goes to such parts and chronic inflammation often results. Serious kidney disease has been developed by sitting constantly with the back near a heated stove. Many sore throats are caused by wearing tippets and scarfs about the neck. The harm results both from overheating and from suddenly cooling this part of the body. It is best that the outer clothing be of different weights, so that it may be changed with the variations of the atmospheric conditions. The necessity of putting on underclothing of different weights may thus, to a great extent, be avoided. The underclothing should be kept clean and changed often, especially if it be of wool.

The feet should at all times be kept dry and well covered. Wet and cold feet are frequently a cause of colds.

498. Cautions about the Clothing.—It is not advis-

able to have the neck or face bundled up closely, even in very cold weather; for in this way colds and soreness of the throat are much more likely to be contracted, local perspiration is produced, and sudden chilling is likely to result.

Tight clothing, no matter upon what part of the body, is injurious. Tight lacing and improper use of corsets, especially by young women, interferes with the proper development of the chest and the internal organs. The human body contains no useless space. The vital organs within the body are of the proper size, and cannot be increased or diminished in bulk without deranging and impairing their functions. Nor can they be displaced without injury. These are facts admitted by anatomists, physiologists, and physicians. Hence the care necessary in having loose clothes about the waist. By wearing tight clothes the heart and lungs are compressed, interfering with the respiration and with the circulation of the blood, while the stomach, liver, and abdominal organs are so displaced as to cause indigestion and otherwise interrupt the functions of these organs.

Tight garters, or elastics, worn below the knee are injurious because they obstruct the proper circulation of the blood in the feet and legs.

Tight shoes, besides being a source of discomfort, are very likely to produce lameness. They are the most frequent causes of corns and bunions, and sometimes produce serious deformities of the feet.

Tight fitting collars and bands about the neck impede the circulation of the blood from the head. Congestion in this part thus results, ending in headaches or disturbances of the vision.

Tight fitting hats frequently cause headaches and neuralgias. In summing up, it is evident that the clothing should be of the proper kind, of the proper weight, clean, and loose enough to admit of perfect comfort to all parts of the body.

LIV.—EXERCISE.

499. Bodily Strength.—The working of the human body has already been compared to the working of a complex piece of machinery (§ 378). It is true that there are many points of similarity between the two, but there are points also of great dissimilarity. For example, a piece of machinery wears out and becomes weakened by use, but as a general rule, the human body becomes more fully developed and increases in strength by judicious exercise.

Bodily strength, to a certain degree, is essential to bodily health. Weak bodies, usually, are not healthy bodies. A person who is physically strong has not only muscular strength, but he has a strong nervous system, a strong circulatory system, and a strong digestive system. His mind is usually capable of great intellectual development, and having much physical endurance, he is able to follow his pursuits in life with pleasure and comfort.

With a person who possesses a weak body the opposite condition generally exists. His nervous system is usually disordered, his circulatory and digestive systems do not perform their functions properly, and be-

cause of a lack of physical endurance he is unprepared to carry on any occupation with either comfort or satisfactory success.

While it is necessary, in order to have good health, that one should have a moderately strong body, it should be remembered that excess of anything is contrary to the rules and demands of nature.

500. How Strength may be Acquired.—The strength of any part of the body is improved by judicious exercise. The need of exercise seems to be instinctively recognized at all periods of life. An infant when awake is seldom quiet, but keeps its legs and arms in almost constant motion; children run, jump, and play because of the natural instinct which demands activity of the body; older persons find exercise in attending to their daily labors, in performing their social duties, in walking, riding, and the multiplicity of movements which a life of activity demands. It will be observed that those persons who are the most active in their habits are, as a general rule, the least liable to disease: they retain their youth for a longer period, and are likely to live to a greater age than those who are of sluggish dispositions and indulge themselves in indolence. The way to preserve one's strength is to use it—not spasmodically nor to an excessive degree, but moderately and regularly. The way to increase the power of any given organ or tissue is by judicious exercise. Even the brain is no exception to this rule; study and thought are sure to add strength to the intellectual powers; the failure to exercise the brain tends to produce mental weakness and imbecility.

501. Exercise of the Muscles.—The muscular system bears so close a relation to the other parts of the

body that exercise of the muscles is conducive to the health of the entire system.

What are the two general classes of muscles (§ 99)?

In what part of the body do most of the involuntary muscles lie? Into the structure of what important organs do they enter?

Describe the action of these muscles. What part of the nervous system has control over them?

To what extent, if any, can their actions be modified by the will?

Where do the voluntary muscles lie? Why are they called voluntary?

Which class of muscles comprises the greater part of the body, the voluntary or the involuntary?

The involuntary muscles are, of course, incapable of being exercised in the same way as the voluntary. But such is the relationship between the two that when the latter are properly used the former are indirectly exercised and strengthened.

502. Direct Benefits Derived from Exercise.—Insufficient and excessive exercise are both detrimental to the health. But the moderate, regular, and judicious use of the voluntary muscles is conducive to the well-being of every tissue and organ. The muscles themselves become larger, and firmer; their strength is increased; their movements become more accurate; they respond to nerve stimulus more readily; and their power of endurance is greatly increased.

503. The muscles are richly supplied with blood vessels and nerves. Exercise causes the blood vessels to be dilated, the circulation of the blood to be accelerated, and as a consequence the heart and circulatory system to be strengthened. The nerves, too, which

supply stimulus to the muscles, are benefited by their activity, and the whole nervous system becomes stronger and more active. The involuntary muscles being likewise strengthened, they enable the internal organs to perform their functions much more perfectly. The appetite is improved and the powers of digestion are increased.

504. The same cause aids in the processes of assimilation (§ 312), and also assists in promoting the removal of waste matters from the system. It strengthens the respiratory system, enlarges the chest cavity and the lungs, and by causing more air to be drawn into the air-cells of these organs increases the efficiency of the oxidizing processes that are going on in the blood vessels.

505. Physical exercise acts as an incentive to intellectual development. Healthy minds often depend upon healthy bodies. The importance of physical exercise to students has in late years been so appreciated that many colleges and schools have well-equipped gymnasiums and playgrounds, and some have special instructors in physical culture.*

506. Effects of Insufficient Exercise.—When we speak of insufficient exercise we mean that the muscles are indulged too long in a state of idleness. Now, if any muscle is allowed to remain unused the

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*Cicero said: "It is exercise alone that supports the spirits and keeps the mind in vigor."

Plato said: "Any one who devotes himself to intellectual pursuits must allow the body to have motion and practice gymnastics."

Another has said: "When we breathe, exercise, eat, bathe, and dress *correctly*, then our powers to grow healthy and beautiful and to evolve higher qualities become limitless."

flow of the blood in it becomes sluggish, it does not readily assimilate nourishment, and the poisonous waste matters are not thoroughly removed from it. As a consequence, it becomes pale and soft, and not responding readily to nerve stimulus, it loses much of its power of contraction. It soon becomes so weakened that it is incapable of performing even a reasonable amount of labor.

Insufficient exercise, as may readily be inferred, debilitates not only the muscular system, but the whole body as well. The nervous system becomes weakened, the circulatory organs lose their vigor, the appetite fails, and the powers of digestion are lessened. Further than this, the processes of assimilation and elimination are hindered, and the body becomes enfeebled and an easy prey to disease. Persons whose occupations are such that they can have but very little exercise are usually subject to ailments of various kinds because of their lack of bodily strength.*

507. Effects of Excessive Exercise. — Moderation is nature's rule respecting all things. Moderation in exercise is as necessary to our well-being as moderation in anything else. Excessive exercise is harmful to the body, and tends to weaken it rather than to strengthen it. The word excessive, when used in this

* "It is a fact that if you take a healthy arm, even a strong arm, a blacksmith's, for instance, and place it in splints for a period of only six months, it will become so small, flabby, weak and useless that he can scarcely use it to lift a teaspoon to his mouth when the splint has been removed. Nor will the arm regain its normal strong and healthy condition until long months of use and freedom from splints have gradually again developed the muscles and restored them to their functional strength. This law holds good over all the muscles of the body."

connection, is a comparative term. What might be just enough for one person may often be an excessive amount for another, and vice versa. The age, sex, occupation, and general condition of the individual are important factors in determining between a proper and an excessive amount of exercise. Exercising for health and exercising for athletic competitions are quite different things. In the former there is too often a tendency to insufficiency, but in the latter there is usually a strong inclination to excess. While it is true that excessive exercise will often produce very strong muscles, it is also true that the muscles may acquire their strength at the expense of other parts of the body. The heart is especially likely to become overtaxed and thus weakened, and the nervous system nearly always feels the effects of excess. Exercise, therefore, should never be indulged in to such an extent as to produce great fatigue. Tired muscles, laborious breathing, and rapid action of the heart are all indications that the body is being overtaxed and is in need of rest. A proper amount of rest is as essential as a proper amount of exercise.

508. Fatigue.—Fatigue may be defined as a sense of being "tired," "worn out," or "overworked." It may affect certain muscles, certain organs, or the entire body. Fatigue is said to be a regulator of bodily activity. It indicates when the muscles have been sufficiently taxed, and serves as a warning that further work or exercising will be injurious or dangerous.

Fatigue probably occurs as a result of a sort of poisoning of the tissues. This poisoning is caused by an over-accumulation of waste matters, especially of carbonic acid gas, in the system. Hard labor, the

increased action of any muscles, hastens the breaking-down of the tissues, and the formation of waste matter. As long as the body is able to remove this waste matter no evil effect is felt, but when the amount of waste produced exceeds the amount that can be removed, fatigue is felt. Thus it is, that if the body is worked or exercised until it is greatly fatigued harm results and the tissues become weakened instead of strengthened.

509. Rest.—Rest is the only way by which the body is enabled to recover from fatigue, of which it is the antithesis. Sufficient rest is essential to health and strength. Sleep is nature's method of giving rest to the entire body, for it is necessary that not only the muscles should have rest, but all other parts as well. Voluntary muscles rest and work as the will requires them to do, but the involuntary muscles rest and work alternately, as nature requires. The heart, though it appears to be working all the time, rests almost as much as it works, its periods of rest being the intervals between its contractions. The stomach rests during the intervals of digestion; and other involuntary muscles have adequate rest between periods of labor (§ 103).

510. Rest and Reconstruction.—In health the processes of reconstruction and repair are carried on with sufficient rapidity to offset the processes of destruction, and hence there is no appreciable loss of strength. The materials necessary for the repair of the wearing-out tissues being present in the body, it is only necessary that the tissues should be in a fit condition to make use of them. If the tissues are overworked they are destroyed faster than they can be repaired, and hence become weakened. Rest, therefore, is a

necessity, because it affords an opportunity to remove all the waste matters and to replace worn-out cells with new. During the intervals of rest, the processes of repair go on rapidly, and the processes of destruction but slowly.

511. Amount of Rest Needed.—The amount of rest required differs in different people, and varies in proportion to the amount of work done. During the time when we are awake, rest should be taken in sufficient amount and with such frequency as to prevent the occurrence of excessive fatigue. Sleep is a mode of rest which is universally required. It should be taken at regular intervals and in sufficient amount to restore to the body the freshness and vigor which it has lost during the hours of wakeful activity. Children, as a rule, require more sleep than adults, and persons who perform manual labor more than those who do not. No rule can be given as to the length of time which one should spend in sleep. The average time demanded by most children is about ten hours out of each twenty-four; but for adults about eight hours is generally sufficient. Proper rest and refreshing slumber do much towards maintaining the strength of the body and preserving its health. Overwork, excessive exercise, and insufficient rest, are alike detrimental to one's physical welfare.*

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*The amount of sleep essential to health differs greatly in different individuals. Bonaparte could endure great fatigue for days at a time with but few hours of sleep. Frederick the Great is said to have required but five hours of sleep daily, and there are many instances in which four to six hours daily have been sufficient.

Alfred the Great recommended that a person do eight hours of

512. How to Take Exercise.—In taking physical exercise three things should be constantly remembered:

1. To exercise enough.
2. To exercise judiciously and in moderation.
3. To allow one's self all the rest that is needed, and to take sufficient sleep.

Another rule might well be added to these, and that is, to take the right kind of exercise. It is self-evident that the same kind of exercise is not equally beneficial to all persons. To promote the symmetrical development of the entire physical structure it is evident that those parts of the body which are the weakest necessarily require the most exercise. We would not say that a blacksmith or a miner is in need of exercise to develop the muscles of his arms. But though he have strong arms, he may have weak legs, or a weak, contracted chest, and then we should say that he needs to exercise his legs or his lungs. So it is with every one, —some parts are as strong as they should be, while other parts are weak and require exercise to strengthen them.

513. Exercise should not be taken for the purpose merely of acquiring great muscular strength, but it should be taken with a view towards promoting one's

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work, take eight hours of sleep, and enjoy eight hours of recreation. The observance of this rule, if practicable, would certainly be very beneficial.

Sir William Jones's couplet on the division of one's time has often been quoted:

> "Seven hours to law, to soothing slumber seven,
> Ten to the world allot, and all to Heaven."

Sir Edward Coke would not sleep so long:

> "Six hours in sleep, in law's grave study six,
> Four spend in prayer, the rest on nature fix."

general health. It should be taken in such a way as harmoniously to develop and strengthen all parts of the body. It should be taken regularly and systematically. Practicing physical exercise for one day and then being idle for two or three days will not prove to be very beneficial.*

LV.—VARIETIES OF EXERCISE.

514. There are two general classes of exercise, *indoor* and *outdoor*. Either of these, if practiced properly, is of great benefit. The outdoor is preferable, but if it is not practicable then the indoor should not be neglected. Some out-of-door sports are of such a nature as to demand very violent exercise, and are so easily convertible into excessive exercise that they should be engaged in only with great circumspection and care. Walking, rowing, swimming, baseball playing, bicycling, horseback riding, etc., are all forms of exercise which, if rightly used, are promotive of good health.

Of the various forms of indoor exercise the most common are swinging Indian clubs, practicing with dumb-bells, boxing, fencing, climbing, using rowing machines, or exercising with systems of ropes, pulleys and weights.

515. Outdoor Exercises.—Walking is the simplest and most natural mode of taking exercise. It is

*Probably the most important thing in taking physical exercise is to acquire the habit of sitting, standing, and breathing correctly. Hard muscles of themselves are not always an indication of health, nor are they always a necessity to it.

usually the most convenient and most pleasurable mode, and is by all odds the best exercise that one can take. It is a form of exercise which is available and suitable to persons of all ages and occupations. It is the natural mode of locomotion for man, and it brings into action all the muscles of the body, strengthening and developing them. Being an exercise which is usually taken in the open air, it is doubly beneficial, in that the body is supplied with an abundance of pure, fresh air.

FIG. 176.—IMPROPER AND PROPER POSITION OF THE BODY IN WALKING.

516. *Walking* strengthens the muscles and increases the power of endurance. It causes one to take deeper and fuller inspirations of air, and thus broadens and strengthens the chest. It increases the appetite and aids the process of assimilation, accelerates the circulation, and tones up the nervous system. In fact, it acts as a strengthener of the whole body.*

*The best tonic for a weak heart is a brisk walk. The majority of weak hearts are weak and flabby because every other muscle in the body is weak,—and this general weakness is due to want of vigorous use. Exercise of the legs and back and arms gives additional and much-needed exercise to the heart, and the heart grows strong by vigorous exercise exactly as every other muscular organ does,—for the heart is a muscle. If a man has no organic disease of the heart, no enlargement, and no functional disorder, plenty of brisk walking will soon dispel his breathlessness and

While walking, the position of the body is of much importance. An erect position should always be maintained. Walk with the shoulders thrown backward and the chin upward. Cultivate the habit of taking full, deep inhalations of air. By so doing you can get the most benefits possible by this mode of exercising.

517. *Running* and *jumping* are modifications of the act of walking (§ 124). They are valuable modes of exercise, but being more violent than simple walking, they produce fatigue much more quickly. For this reason they are not suitable to many persons. They bring into action all the muscles, and exercise the whole body. Running and jumping should not be used as modes of exercise by persons who are quickly fatigued by them. Breathlessness, palpitation of the heart, and a feeling of faintness are all indications that harmful results are apt to occur.*

518. *Swimming* is an art with which every person ought to be familiar. Besides being a valuable and pleasurable mode of exercise, it may some-

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heart-weakness, other things being equal. The muscular inactivity of many persons is the cause of more ill-health than any other single thing.

*"The natural instinct with children of delicate physique is to stay within doors. The pleasantest day seldom tempts them into the open air; and even when they do go, the inherent sense of their own weakness keeps them from joining in the sports of their playmates. Their parents generally help them in this tendency. Because they are known to be delicate, they are kept from the very things which might enable them to grow strong. The majority of them could be greatly helped by being made to join in certain games and forced to follow a systematic course of training. Through the lack of systematic and regular exercise, many a child has been prevented from growing strong and healthy."

times be the means of saving a human life, either one's own or that of another. As an exercise it brings into action all the muscles, and tends to give general bodily strength.

Games and sports—tennis, golf, baseball, rowing, and skating—all produce good results, because they are indulged in for pleasure, and being outdoor sports they give to the participants plenty of fresh air. They bring into action most of the muscles, and thus promote the general strength. It should be remembered, however, that they should be indulged in moderately, for otherwise harmful results may be produced.

FIG. 177.—IMPROPER AND PROPER POSITION OF THE BODY WHILE BICYCLING.

Bicycling is at the present time, perhaps, the most popular mode of taking out-of-door exercise. It is adapted to both sexes and to persons of all ages. Indulged in to a moderate extent it tends to produce strong, healthy bodies. It brings into use all the muscles, accelerates the circulation, strengthens the nervous system, and tones up the whole system.

Bicycling to excess acts in a detrimental way, and may produce harmful results or even permanent injury. Long rides and trials of speed overtax the strength, and should not be indulged in. It is well to remember that what would be a moderate amount of

bicycling for one may be an excessive amount for another. The amount of such exercise should always be proportioned to the general condition and strength of the persons taking it, and should never be continued to the point of great fatigue.

519. Care of the Body while Exercising.—A few plain rules on this subject are well worth noticing:

1. Do not indulge in any violent exercise within two hours after eating a hearty meal, or within half an hour before eating.

2. Special attention should be paid to the clothing. It should be light in weight, and whenever practicable made of wool. It should fit the body loosely, so as to admit of free movements of all the muscles.

3. After having been engaged in any violent exercise, if the body has become very warm and wet with perspiration, care should be taken to avoid catching cold. One should not sit upon the bare ground, or where there is a draft. It is well to throw a blanket or coat over the shoulders, and to walk about until cooled off, or until the clothing can be changed.

4. After exercising take a warm bath as soon as convenient. Then rub down thoroughly with a dry towel and change the clothing. Many of the ill effects which follow violent outdoor exercise are due to carelessness and to the neglect of one or the other of the above rules.

520. Indoor Exercise. — Many persons find it impossible to take a sufficient amount of outdoor recreation; hence, they must necessarily resort to some form of indoor exercise.

All such exercise should be carried on in a systematic way. It should be of a kind best suited to strengthen

the weaker parts of the body, and should be conducted persistently and with much regularity; but the rule of moderation should be carefully observed.

Exercise of this kind may be practiced both in the home and in the school-room with much advantage. In the school it would be well if a definite period of time each day were devoted to the performance of certain gymnastic exercises. These serve as a rest to the body, accelerate the circulation, and render the acts of breathing more powerful. Varied motions may be produced with wands, dumb-bells, etc., or merely with closed hands, so that approximately all the muscles of the body are brought into use. Such exercises should not be continued until they produce fatigue. One should begin lightly, increase slowly, and practice regularly. After a time the body becomes stronger and more used to exertion, and an amount of exercise may be taken with comfort which in the beginning would have been impossible.

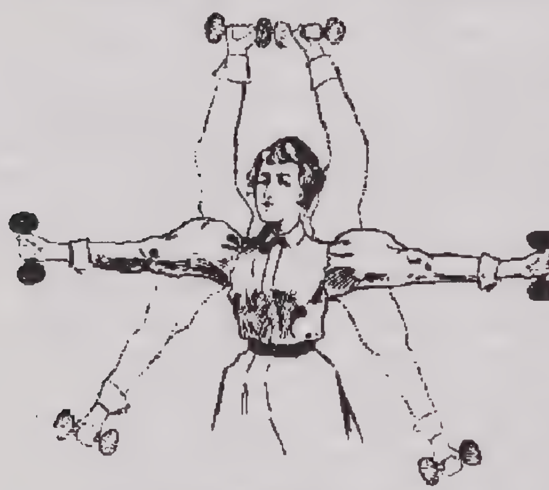

FIG. 178.—EXERCISE WITH DUMB-BELLS.

521. Varieties of Indoor Exercises.—A modern gymnasium contains a great variety of appliances for

bringing into action all the muscles of the body. Performing with dumb-bells and Indian clubs is a popular as well as a beneficial mode of promoting physical culture. The various motions which are executed in connection with their use educate and strengthen the muscles of the arms, chest, and back.

Practicing with the *rowing machine* is excellent exercise. It brings into action all the muscles of the body, accelerates the circulation, and increases the power of breathing.

522. **Boxing and Fencing** demand quick and accurate motions of all the muscles and also require constant attention on the part of the eye and the mind.

523. **Health Exercisers, or Home Exercisers,** as they are called, are appliances usually constructed of ropes, pulleys and weights, or elastic cords, so arranged as to give any desired amount of resistance and to enable one to perform all kinds of motions. The use of them is very beneficial to muscular development.

There are many other appliances used for indoor recreation, such as ladders, cross-bars, trapezes, ropes, rings, all of them of some value if used rightly.*

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* "If one goes to a gymnasium he should thoroughly understand how to begin his exercise. The latter part of the afternoon is the best time. He should wear the proper amount of clothing, and do his work quickly and systematically. The work at first should be light, and never carried to the point of fatigue. He can begin with the chest weights. With a light weight in each hand he should go through the various movements. Ten times for the first day is sufficient. Then a few moments with the wooden dumb-bells, ending up with a slow run around the track, for a distance equal to a quarter of a mile. This will be found to be enough and not too much for most beginners, and there will be no resulting stiffness or soreness next day."

524. Every One Can Do This. — A prominent instructor in physical culture says:

If a person will daily walk about five miles, and will practice each morning and evening the following simple exercises with the aid of a cane or stick, he will receive as much physical exercise as is essential to health. The exercises are as follows:

Fig. 179.—Exercising with a Cane.

1. *To develop the upper part of the arms.*—Grasp the cane firmly at both ends with the hands, and hold it across the chest so that the middle of the cane rests against the body. Now drop the hands downward to the full length of the arms, then draw them quickly back to their first position, with the cane resting against the body. Continue this exercise for thirty seconds.

Holding the cane as before, push it upward above the head to the full length of the arms, then bring it quickly back to its original position. Continue this for thirty seconds.

2. *To develop the forearm.*—Grasp the cane near the middle with one hand. Then holding it at arm's length from the body on a level with the shoulder, twirl it backward and forward. Continue this for twenty seconds. (Fig. 179.)

3. *To strengthen the muscles of the sides.*—Grasp the cane at both ends with the hands, then holding it above the head at arm's length bend the body from side to side as far as possible. Repeat this exercise ten times.

4. *To strengthen the muscles of the back.*—Hold the cane as in the preceding exercise. Then bend the body forward and backward as far as possible without losing the balance. Repeat several times.

A daily walk of five miles and these exercises are approximately the amount of exercise to be taken. If the walking is not done, then an equivalent should be taken in some other form of exercise.

LVI.—POSTURE.

525. Effects of Habitual Posture.—In connection with the study of exercise, a subject which is of much importance to everybody, is the effect of habitual posture upon one's health and happiness. Young persons, and especially school children, are too often careless of the positions which they assume in sitting or standing, not realizing what a great influence such positions have on the development, beauty, and symmetry of their bodies (§ 115).

526. Sitting.—An important rule which everybody should observe is this: *Sit erect.* Most persons are

A B

C D

Fig. 180.—A, A Good Posture; B, C, D, Improper Postures.

inclined to sit in a stooping posture. This is frequently the result of careless habits, though often the position and height of seats and desks are the immediate cause.

Habitually sitting in a stooping posture is detrimental to health and destructive to beauty of form. It is the chief cause of "round shoulders," which, to say the least, is an unsightly deformity. A stooped position narrows the chest and diminishes its capacity, thus producing, in many cases, weak lungs. It also tends to send an over-supply of blood to the head, and this after a time will so affect the eyes as to cause defective eyesight. Careless habits in sitting, when they have been once acquired, are very difficult to overcome, and the results which are produced by such habits are seldom entirely corrected in after life.

FIG. 181.—PROPER POSTURE IN STANDING.

For one who finds it difficult to sit in an erect position with comfort, the persistent practice of the following simple exercise several times daily for a month or a year, will be found very beneficial:

Sit perfectly erect with the shoulders thrown back and the head tilted backward. Then take a long, slow, deep inspiration, filling the lungs completely with air. Hold the breath a moment, and then slowly let the air leave the lungs until the chest assumes its former size. Repeat this several times in succession.

527. **Standing.**—Not only should one sit erect, it is equally important and necessary to *stand erect.* In

standing, the weight of the body should rest equally upon both feet (Fig. 181). A common and injurious habit is that of standing so that nearly all the weight of the body is thrown upon one foot. This position, by throwing the body to one side, is very likely to produce deformity, and especially a curvature of the spine. Standing in a stooping posture affects the body just as sitting in a similar posture would do.

FIG. 182. — IMPROPER POSTURE IN STANDING.

528. Postures in sitting and standing have a special influence upon the growth and development of the bones. Bones, to be properly developed, should grow in a proper position. If the body is frequently in a twisted condition, we can only expect that the bones will become distorted. Thus it is that deformities, which have been acquired in early life on account of faulty habits in sitting and standing, can seldom, if ever, be corrected in after life. (See Fig. 183.) Proper exercise of the body will often overcome a tendency to assume improper postures.

LVII.—SANITATION.

529. Cleanliness.—What is the first general law of hygiene (§ 468)? This law includes several particulars—can you name them? Why should the skin be kept clean (§ 487)? Why should the teeth be kept clean

(§ 203)? What may we understand by "unclean" food (§ 481)? Why should such food be avoided? Why should every one avoid the use of tobacco? If unclean substances are admitted into the alimentary canal, how is the blood affected thereby? What is meant by impurities of the blood? Name the channels by which impurities are removed from the blood. Why should one never breathe impure air? Why is impure water harmful? Are alcoholic liquors ever pure in the strict sense of the word?

From the answers you have given to the foregoing questions we may deduce the following special rules with reference to cleanliness:

Drink pure water.

Breathe pure air.

Keep the outside of the body clean.

Eat wholesome food, free from deleterious impurities.

Admit no poisons into the digestive canal. Shun alcohol and tobacco.

FIG. 183.—EFFECTS OF IMPROPER POSTURE IN STANDING OR SITTING.

530. A careful observance of even the first two rules will go very far toward preserving one's health. But in order to be able to observe them it is necessary to pay heedful attention to the character of one's surroundings. If you live in a locality where the atmosphere is polluted from any

cause, you cannot breathe pure air. If the water you drink is derived from unclean sources, you cannot avoid its impurities. If your home is in an insalubrious location, you will suffer from the effects of the noxious impurities which exist there.

531. Practical Sanitation Laws.—Sanitation, literally speaking, includes any and all measures of hygiene which are related to cleanliness and the consequent prevention of disease. As here used, the term refers more particularly to those measures which have to do with our dwellings and with our general surroundings. Proper sanitation not only affects the individual, but the masses of the people.


FIG. 184.—PROPER POSTURE IN STANDING.

532. In Cities.—Where people live in communities large enough to form towns or cities, practical sanitary laws are of the greatest importance to the welfare of all. The town or city should be kept clean, its streets should be kept free from filth, the garbage and other accumulations should be properly removed, and there should exist a proper system of drainage or sewerage.

A neglect of these things is sure to produce disease and to imperil the life and health of every inhabitant.

Almost every city in the United States has its health board, or sanitary board, the duty of which is to look after the general sanitary condition of the city.

533. In the Country every head of a household should be his own "board of health." He should see to it that the health of his family is not imperiled by impure water, noxious air, or unwholesome food. Proper care with reference to these things will prevent much sickness and suffering. The barn and stables should never be so situated that the drainage from them can by any possibility find its way into the well or spring which supplies the family with water. Filth of any kind should not be allowed to accumulate near the dwelling. Outhouses should be kept scrupulously clean. Sleeping chambers should be well lighted and well ventilated. All the laws of hygiene should be carefully observed and enforced.

The greater part of the sickness among farmers and their families is caused by the neglect of these plain laws of sanitation.

534. The Dwelling.—The location of one's dwelling has much to do with his health and happiness. A house improperly located is often the direct cause of ill health or disease. The ideal situation of a home which would be the most favorable to the preservation of health, may be described as follows:

It should be on dry ground, not near a swamp or slowly flowing river.

If in the country, it should be upon elevated land where it is exposed to plenty of sunlight.*

* "The direct rays of the sun are among the most powerful of germ-destroying agents. The most deadly germs perish within a few minutes under the direct rays of the sun. Most germs are also killed by the action of diffused light. The value of the sunlight as a disinfectant, however, is above estimate, hence the importance of admitting the sun to every portion of our dwellings."

If in the city, it should be in a cleanly locality, and freely accessible to both sunlight and fresh air.

A dwelling should always be properly heated, properly ventilated, and properly drained. Dark houses with damp cellars and insufficient or improper drainage are always detrimental to health.

LVIII.—THE AIR WE BREATHE.

535. Practical Review.—What is meant by the breath? What is meant by *a* breath? What two acts constitute a respiration? Explain how we breathe (§ 336). Name all the organs that are in any way concerned in the acts of respiration. What part of the nervous system has control over these acts (§ 390)?

How often do you usually breathe in a minute? Can you by your own will control the rapidity of your breathing? What might often be the result if the respiratory muscles were entirely voluntary?

Is it possible for one to expel the air entirely from the air-cells of the lungs? About what is the average capacity of the lungs? About how much air is taken in at a single respiration (§ 343)? In what respects does the air which is expired differ from that which is inspired?

Why is it necessary for one to breathe? What change takes place in the blood through the act of breathing? Why is this change necessary (§ 344)? How does the purity of the air affect the thoroughness of this change? Why, then, is pure air always desirable?

536. The Air.—What is pure air (§ 339)? Of what two gases is it composed? Which of these is the active, or positive, element? Why is the other said to be negative? What would be the consequence of breathing air which contains too much oxygen; of breathing air which contains too much nitrogen? What is the proportion of nitrogen in the air? What is the result of breathing carbonic acid gas? What becomes of the carbonic acid gas which is constantly being formed and liberated in the atmosphere?

How much carbonic acid gas is given off from the lungs of each person in the course of twenty-four hours (§ 347)? Suppose that a person is confined all day in a very close room, what is the effect on the air which he must breathe? What will be the effect on his health? From your answers to these questions deduce a reason why living rooms should always be well ventilated.

537. Impure Air.—Samples of outdoor air, taken at numerous places, at various elevations, and at all hours of the day and night, show on analysis a composition approximately as follows:

	Per cent.
Oxygen	20.96
Carbon dioxide (carbonic acid gas)	.03
Nitrogen	79.01
Ammonia	traces
Watery vapor	in varying quantities

If other substances, either gases or solids, are found in the air, they exist there as impurities.

Air is impure when it contains foreign substances, or when any of its constituents exist in too large or too small a proportion. Foreign substances which render the air impure may be gaseous or solid.

Solid impurities in the air are held in a state of suspension. They consist of dust, soot, particles of organic matter, bacteria and other micro-organisms, and, in fact, particles of any kind which are light enough to float in the air.

Gaseous impurities consist of gases and vapors which result from the combustion of fuel, from the exhalations of men and animals, from decomposition and fermentation of organic matter, etc.

If these impurities were allowed to accumulate in the air it would soon be unfit to support any kind of life. Nature, however, puts into action certain processes which constantly tend to preserve it in a comparatively pure state. Thus the winds tend to scatter the impurities, the rains to absorb them, and the process of oxidation to destroy them.

The air of some localities is much more impure than that of others. In cities it is much more impure than in the country; in low, marshy places, more than in elevated localities.

538. The Effects of Impure Air.—The laws of health demand that the body be supplied with fresh, pure air, and plenty of it. Impure air is harmful in many ways. The character and degree of its harmfulness vary with the character and amount of its impurities.* Solid

*The most common and usually the most serious vitiation of the air of inhabited apartments is that due to respiration. There is constantly passing off from the lungs and skin of human beings a mixture of carbonic acid gas, aqueous vapor, and organic matter; of these the carbonic acid gas and the aqueous vapor are comparatively harmless, but the organic matter, though present in very small proportions even in air quite foul, is extremely poisonous and detrimental to health.

impurities in the air are especially likely to affect the respiratory organs, because they come directly into contact with these organs. They cause irritation of the air passages, and often inflammation of the lungs themselves. Coal miners, metal miners, and steel grinders are often subject to throat and lung affections due to the inhalation of particles of solid matter.

Impure air is the cause and disseminator of many diseases. Bacteria floating in the air are likely to produce disease, and such diseases as influenza and malaria are carried great distances through the air. Gaseous impurities in the air often produce marked symptoms of disturbance of the system. Sewer gas is a dangerous impurity. The breathing of it may not directly cause disease, but it tends to enfeeble the body so that it is easily attacked by it. Coal gas, when breathed, produces headache, dizziness, and if in sufficient quantity, asphyxia. Air after having been breathed is poisonous. Why? If reinhaled, even for a short time, this air will produce headache, dizziness, languor, and nausea. Persons who live in a crowded apartment and who congregate in rooms that are poorly ventilated, breathe this kind of air, and its ill effects are generally very apparent.* Persons who are habitually in such surroundings become pale and languid, their appetite is impaired, their bodies enfeebled, and they become specially susceptible to

*After the battle of Austerlitz, 300 Russian prisoners were confined in a cavern, where 260 of them perished in a few hours for want of pure air. The captain of the ship Londonderry, during a storm at sea, shut the hatches. There were only seven cubic feet of space left for each person, and in six hours many of the passengers were dead.

disease. It is a well-known fact that contagious diseases spread rapidly in densely populated and poorly ventilated localities, and in such surroundings they are very fatal. It is also true that in cities which have wide streets and many parks there is less sickness than in those in which the streets are narrow and there is an absence of parks.

539. Ventilation.—Impurities in the air, while they cannot be destroyed, can be to a great extent scattered and diluted. This should be done as much as possible, especially in dwellings and in rooms where persons congregate. The process by which impure air is removed and then replaced by fresh air, or by which it is diluted with fresh air, is called ventilation. Proper ventilation of rooms is often a difficult problem because of the difficulty of admitting fresh air and at the same time avoiding drafts and all sudden changes of temperature. All modes of ventilation should make provision for both the egress of foul air and the ingress of fresh air.

In the summer time, and in climates which admit of it with comfort, ample ventilation is secured by leaving the doors and windows open, thus allowing the fresh air from outside to circulate freely through the house. In stormy or cold weather and in cold climates, when the doors and windows are closed, this result must be attained by some other means.

The amount of fresh air required in a room depends both upon the size of the room and upon the number of persons occupying it. If a large room is occupied by only one or two persons, enough fresh air may be admitted through the cracks about the doors and windows; but if it is occupied by several persons, some

means must be devised of increasing the supply of fresh air and facilitating the removal of impure air.

Where open fires or grates are used for heating purposes, a fair amount of ventilation is produced; the impure air is drawn out through the chimneys, and fresh air enters rapidly through the crevices about the doors and windows.

Where rooms are heated by means of hot-air furnaces much fresh air is forced into them, the heated air usually being drawn from out of doors through the furnace, and sent into the rooms.

In rooms where there is likely to be an insufficient amount of fresh air the arrangement of one or more windows as shown in Fig. 185 will be advantageous.

Lower the top sash, b, about six inches, so that its lower edge overlaps the lower sash, a. Have the top open space filled by a well-fitting board, c. By this arrangement fresh air is admitted through the space between the two sashes, in the directions of the arrows d e, d e.

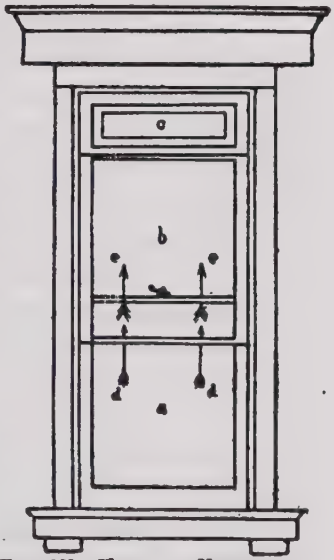


FIG. 185.—HOW TO VENTILATE A ROOM BY MEANS OF A WINDOW.

This method will supply an abundance of fresh air to a room without producing perceptible drafts and without suddenly cooling the room. The effect is more satisfactory when several of the windows are treated in this manner.

In rooms and dwellings many forms of ventilating apparatus may be used. All of them operate upon the same principle, supplying one opening or set of openings for the entrance of fresh air, and another opening for the egress of impure air, the latter usually connected with a shaft or chimney to increase the force of the current. "A room cannot be properly ventilated without an efficient arrangement for the admission and circulation of pure air. Nothing can be more absurd than the frequently witnessed attempt to ventilate a room by providing it with a ventilating shaft connected with proper ducts and foul-air openings, but without any provision for a supply of fresh air."

The importance of this subject is recognized, at present, to such an extent that architects in planning a building are required to pay particular attention to its ventilation.* The ventilation and the heating of a building must be considered together; for a successful working of each will depend upon the conditions of the other.

These are subjects which should be carefully considered by every person who contemplates the building of a home. They embrace so many particulars that only the most general rules can be given in a school text-book.

*A peculiar article manufactured in France is porous glass for windows. This is declared to possess all the advantages of the ordinary window-framing, and, while light is as freely admitted as through the medium of common glass, the "porous" also admits air. The minute holes with which this glass is intersected are too fine to permit of any draft, while they provide a healthful, continuous ventilation through the apartment.

LIX.—ILL HEALTH AND DISEASE.

540. The Causes of Disease.—What is health (§ 470)? When all the parts of the body are in perfect and harmonious working order what is the result? Suppose that one of the organs, as the stomach, is overworked or injured, what is the result?

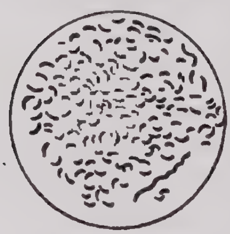
Disease signifies an absence of health. It is an abnormal condition, and implies a faulty working of one or more of the various parts of the body. If the body were never to become diseased, its mechanism would simply wear out in old age, and death would come merely as a result of this wearing out. Impure air, unwholesome food, overwork, extremes of heat and cold, worry, sorrow, all affect some part or organ of the body; and if one organ imperfectly performs its work, other parts or organs become affected, and the result is some form of disease.

Disease is generally, therefore, the result, directly or indirectly, of unhygienic living. Besides the general causes of disease already mentioned, over-exertion, loss of sleep, want of exercise, dampness of dwellings, intemperance, and uncleanliness of the skin may be named as among the most common means by which physical health is impaired or destroyed.

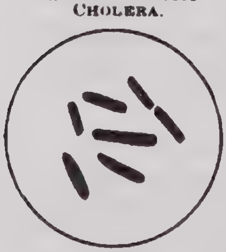
541. Diseases are generally spoken of as being of two kinds: (1) infectious or contagious, and (2) non-infectious. Those of the former class, as a rule, are communicable, that is, they may be contracted by one person from another. Those of the latter class are not

GERMS, OR BACTERIA, OF CONSUMPTION.

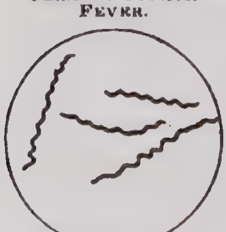
The germs themselves are invisible to the naked eye. In this and the following cuts they are pictured as seen under a very powerful microscope.



GERMS OF ASIATIC CHOLERA.



GERMS OF TYPHOID FEVER.



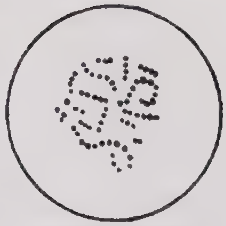
GERMS OF RELAPSING FEVER.

communicable. The prime cause of each contagious or communicable disease has been thoroughly demonstrated to be a specific germ, always characteristic of the disease. The disease is a direct result of the invasion of the body by the germ, or of certain poisons generated by the germ while it is performing its destructive agency in the tissues. Such diseases as consumption, smallpox, typhoid fever, diphtheria, scarlet fever, and measles, are all caused by germs, each disease having its own specific micro-organism.

542. Bacteria. — The word bacteria in its general sense is a name applied to the very lowest and very smallest forms of plant life. The bacteria are in reality minute vegetable growths, so minute as to be only visible by using a microscope of high power. Their average length is probably about one thirty-five thousandth of an inch, and some are even smaller than this. They are of various kinds and of various shapes. Some are spherical in shape, some rod shaped, some ovoidal, some spiral, and some of various irregular forms.

Bacteria grow and multiply very rapidly. They multiply by a process

of division,—that is, a cell divides into two, each of these again divides into two, and so on indefinitely. It is estimated that if nature had not provided a means for their destruction, within a few days enough bacteria would be produced from a single one to fill the ocean—so rapidly do they multiply.



GERMS OF PYÆMIA.

Indeed, after a short time, if all lived, there would be enough bacteria to devastate the earth. Nature, however, provides means for their destruction to a great extent. The winds and rains scatter and destroy them; the sunlight is very destructive to them; some bacteria destroy others; vast numbers are destroyed in the alimentary canals of men and animals; and in various ways an excessive production of these germs is prevented.

MALIGNANT PUSTULE GERMS.

GERMS OF ERYSIPELAS.

Bacteria grow and multiply best under suitable conditions, where there must always be warmth and moisture. This form of life is not, as a rule, destroyed by cold, many forms assuming vigorous growth after having been frozen in ice for many days. Boiling water and steam, however, always destroy them.*

GERMS OF PNEUMONIA.

*"Bacteria are a class of little organisms through the agency of which all of the phe-

BACTERIA FOUND IN THE SALIVA.

543. Action of Bacteria.—Bacteria are, no doubt, the most wide-spread of all organisms. They exist in the air, the water, and upon the surfaces of all bodies. Different kinds of bacteria have different actions; their action, however, is nearly always concerned in the process of decomposition. Thus the yeast plant growing in a solution of sugar has the power of decomposing the sugar into alcohol and carbonic acid gas. Another form of bacteria causes milk to sour, converting milk sugar into lactic acid. Still another form causes butter to become rancid, or cheese to become strong. A most important action of bacteria is that of decomposing organic matter so that it may provide elements for the maintenance of organic life.

544. Disease Germs.—Many of the forms of bacteria are not only harmless, but are of use in some way to mankind. There are, however, as we have already said, certain kinds which cause disease, if they enter the body under conditions suitable to their growth. These forms of bacteria are called disease germs, and each of them, when existing under suitable conditions, produces important changes in the tissues and thus causes its characteristic disease.

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nomena of an organic life take place; they are the agencies, so to speak, without which organic life with its constant changes would be impossible, and it must be ever remembered that without the presence and constant activity of these little bodies there would be no life in nature.

"The infinitely large majority of bacteria are not only harmless, but without them the world would be an inert mass of inorganic matter."

545. The specific germs of the many contagious diseases have been discovered and studied within recent years, and their connection with those diseases has been definitely established. These germs, in order to multiply and produce their characteristic diseases, must have suitable surroundings.* A strong, sound body does not readily submit to their attacks; a weak, unhealthy body is an easy prey to them. In other words, so long as one's system is in a thoroughly vigorous condition he need have but little fear from the inroads of these insidious micro-organisms.

Disease germs exist in large numbers in unhygienic localities, and as persons who live in such surroundings are usually weak and ailing, they are especially susceptible to their ravages.

546. Disease germs enter the body mainly through the mucous lining of the stomach and bowels, and through the mucous lining of the respiratory system. They are taken into the system usually with food or drink, or with the air that is breathed, and if the body

*"Nature comes to the assistance of mankind, and protects many by destroying these germs even after they have invaded the system. There is inherent in all animals, and manifest to a greater or less extent, a physiological resistance of the infectious diseases. There is no doubt but that every adult has at some time unawares entertained the germs of the contagious diseases, and has at some time come in contact with them; has breathed them into the lungs; has taken them in the drinking-water; has swallowed them with uncooked food; has carried them in the clothing and in the hair; has handled them clinging to some old book or paper; and has brought them from some hiding-place where they have lain for years. But bacteria alone, even though of the most virulent type, are not capable of causing disease, unless the conditions are favorable. If this were not so the world would long since have been depopulated."

is not in a suitable condition for their growth they are all destroyed within it. If, however, the opposite be true, they immediately begin their development and their work of destruction.

547. Prevention of Disease.—Disease is a condition which is certainly preventable to a very great extent. A healthy body and clean surroundings are the greatest enemies to disease. If one would live according to the rules of hygiene which have been explained in the preceding pages, he could keep his body in such a condition that disease germs could not thrive within it; and if the locality in which he lived were kept in a sanitary condition, disease germs could not exist there.

Where these pests do exist it is necessary to destroy them as completely as possible. This is done by some process of disinfection.

548. Disinfection.—The object of disinfection is to prevent the spread of infectious diseases by destroying the specific germs by which they are caused. Pure air, pure water, and sunlight may be said to be nature's disinfectants. Where they are found but few disease germs can exist. In many cases, however, these are absent or insufficient, and then other means of disinfection must be devised.

549. The following recommendations of the American Public Health Association are of much value:

The three methods of disinfection are, first, by fire, destruction by burning; second, subjecting anything to be disinfected to superheated steam or dry heat; and third, by the use of chemical germicidal poisons.

For disinfection of clothing, bedding, and rags the following is recommended:

1. If of little value, complete destruction by burning;

2. Boiling for at least one half hour;

3. Exposure to superheated steam, temperature 221° F., for ten to twenty minutes;

4. Exposure to a dry heat for two hours at a temperature of 230° F.

For furniture and articles of wood, leather, and porcelain: Washing frequently with a 2-per-cent solution of carbolic acid.

For the person: The hands and general surface of the body of the attendants of the sick, and of convalescents, should be washed with one of the following preparations:

1. Solution of chlorinated soda, one part to ten of water;

2. Carbolic acid, 2-per-cent solution;

3. Mercuric chloride, 1 part to 500 of water;

4. Carbolic acid, 5-per-cent solution.

For disinfection of sick rooms:

1. First rub the surface of the walls and ceiling with a piece of new bread, if the walls are painted or covered with paper. This is the best method to detach any germs.

2. Then fumigate with sulphur dioxide or fumes of burning sulphur for twelve hours, using at least three pounds of sulphur for every 1,000 cubic feet of air-space in the room.

3. Finally wash the walls with either mercuric chloride solution, 1 to 1,000; or carbolic acid, 2-per-cent solution.

For excreta in sick room one of the following:

1. Chloride of lime, 4-per-cent solution;

2. Carbolic acid, 5-per-cent solution;

3. Sulphate of copper, 5-per-cent solution.

For closet vaults, pour in a liberal quantity of

1. Mercuric chloride, 1 part to 500 of water; or
2. Carbolic acid, 5-per-cent solution.

The infectious character of the dejections of patients suffering from cholera and from typhoid fever is well established. They are as dangerous in mild cases as in severe and fatal ones. It is probable that epidemic dysentery, tuberculosis, and perhaps diphtheria, yellow fever, scarlet fever, and typhus fever may be transmitted by means of the discharges of the sick. It is, therefore, important that these should be thoroughly disinfected.

In cholera, diphtheria, yellow fever, and scarlet fever, all vomited material should be looked upon as infectious. And in tuberculosis, diphtheria, scarlet fever, and infectious pneumonia the sputa of the sick should be destroyed by fire, or thoroughly disinfected.*

Disinfection is always to be carefully supervised by a competent individual, and, as a rule, people should never entrust the disinfection of materials to servants. Where it is to be presumed that any locality, room, out-building, piece of clothing, or any other material is the bearer of infectious or dangerous contagion, it will be a saving of time and expense to secure a trained and efficient sanitarian to superintend the process of disinfection.

550. How to Guard Against Contagious Diseases.—

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*Many people do not understand the meaning of the word disinfection. To them, anything that will destroy offensive odors is a disinfectant. To the masses, the purpose of disinfection is to destroy the offensive odors in a sick room, a closet vault, or a decomposing mass. The true object of disinfection is to destroy the specific infectious germs which give rise to disease.

Contagious diseases are spread from one person to others in a variety of ways.

Scarlet fever is very easily contracted, especially by children, and it is very contagious. This disease is spread by means of the discharges of the nose and throat, and especially by the scales which occur upon the surface of the skin during the progress of the disease.

Smallpox, *measles*, and *whooping cough* are spread by means of the discharges from the body, and are very contagious.

Typhoid fever is rarely contracted by direct contact, but by introducing into the body germs of the disease. These germs come from the discharges from the body of the patient, and generally find entrance into the system through contaminated drinking-water, or impure milk, or improper food.*

Diphtheria is a most dreaded disease. It is communicated from one person to another by the saliva and secretions from the throat, which, drying, are converted into fine dust. If this dust be breathed by other persons, the germs find their way into the body, and the disease is likely to be produced. Poor drainage and insufficient sewerage are no doubt frequent causes of diphtheria.

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*"When there is danger of pollution or a suspicion of disease germs, and a suitable filter is not in use, the water should be boiled, as boiling destroys all disease germs in ten minutes." (Sternberg.) If boiling does render drinking-water rather unsavory, it has the advantage of being effectual in the face of danger from infection, and it is within the reach of the most impecunious. Next to the air we breathe, water is probably the most important element in nature, and it should not only be pure but abundant.

Consumption, or *phthisis*, is a disease the seat of which is in the lungs. This disease causes more deaths than any other. It is an infectious disease, and is spread chiefly by dried expectoration of those suffering from it. This dried expectoration is quickly converted into fine dust, which, floating in the air, carries germs of consumption with it to be breathed by other persons.*

To prevent the spread of contagious diseases, remember that all discharges from the nose, mouth, skin, etc., are likely to produce infection in other persons.

Isolation, perfect cleanliness, and disinfection are all necessary to the prevention of the spread of contagious diseases.

No one should go from a sick room into the presence of other persons until he has changed his clothing and washed his hands, face, and head.

The clothing of the person afflicted should not be worn by any one else, and none of his bed clothing

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**To Prevent Consumption.*—Those who are well should remember that it is an infectious disease, communicated principally by swallowing the germs, by inhaling them, or having them introduced through a wound.

Therefore, do not buy or use food that has been handled by a consumptive. Do not share the food or drink of a consumptive. Do not sleep with a consumptive.

Do not put coins or small articles in vour mouth that may have been handled by a consumptive.

Do not kiss any one on the lips if he has a cough. Do not take food without first washing your hands.

A consumptive person should spit in a cup or wide-mouthed bottle, containing a little carbolic acid and water, and frequently washed with hot water. He should never spit on the street, or floor of house, or cars. .

should be used by others until thoroughly disinfected.

One should not go near the sick person unless necessity demands it.

The lips should not be touched to cups, spoons, food, or drink, which have been in the sick room or which the sick person has handled.

When the person has recovered, everything that he has touched or that was in his room should be thoroughly disinfected.

551. **Alcohol and Diseases.**—The drinker of alcoholic liquors seldom recovers speedily from disease, and he is always the most likely to be attacked by it. The general health of his system has been impaired, and his body is in a suitable condition for the development and growth of disease germs.

Many a young man has died of disease who, if he had not been a drinker of alcohol, might have lived to an advanced age.

The appetite for alcoholic drinks—alcoholism—is said to be itself a disease. Children of parents addicted to the alcohol habit have often an uncontrollable appetite for strong drinks. This may well be called a disease which is the result of inheritance,—an hereditary disease.

Statistics show that a large proportion of persons afflicted with insanity are the descendants of drinkers of alcoholic liquors; they show, also, that the children of intemperate parents are frequently subject to epilepsy or fits; and that in many cases of idiocy or weakmindedness, the lack of intellect is directly or indirectly traceable to the use of alcoholic beverages by parents or other ancestors.

LX.—THE CARE OF THE SICK.

552. **The Room** occupied by the sick should be situated in a quiet part of the house, where plenty of sunlight may be had. Sunlight and fresh air are direct enemies to disease germs, and are admirable disinfectants. A bright, cheerful, sunny room tends to hasten recovery. A dark, gloomy room retards recovery, and is favorable for the breeding of disease germs.

553. *An abundance of fresh air* in the sick room is of the greatest importance. If there is an open fireplace it will be of much advantage in promoting ventilation. If a proper change of air is not otherwise provided, see that the windows or doors are opened enough to supply an abundance of outdoor air. The patient may be protected from drafts and from the sensation of chilliness while the room is being aired, by using screens about the bed and extra bedclothing upon it. Offensive odors and the smells of the kitchen should not be allowed to enter the room. If the room becomes close, and the air in it seems foul, the patient may be completely covered with blankets and the windows thrown open until the room is thoroughly aired.

554. *The furniture in the room* should be only such as is absolutely necessary. All useless bric-a-brac and draperies should be removed. It is better to have the floor bare, with rugs or strips of carpet placed here and there so as to deaden the sound when walking. The chairs should be hard-bottomed ones; upholstered furniture is entirely unsuitable for a sick room. Such

furniture soon becomes a veritable nest of dirt and germs. An iron or brass bedstead is the best, and a mattress should be used, never feather beds.

555. Quiet.—Avoid all unnecessary noises that would be apt to disturb the patient. One should not walk about the room with squeaky shoes; and care should be taken that the hinges of the doors do not creak. Sick people are very easily disturbed by noise, especially sudden sounds, as the slamming of blinds or doors. When conversing in the presence of a sick person, one should always talk in his natural tone of voice; whispering is very annoying, and often tends to produce a sense of alarm in the patient. Do not permit sympathizing friends to annoy the sick one by frequent visits and long conversations. Many a person has been killed by well-meant but mistaken kindness. Whatever is said to the patient should be of a cheery, pleasant character calculated to cause forgetfulness of pain. A smiling countenance, a hopeful look, a pleasant manner in the presence of the sick dispel gloomy thoughts and are in themselves potent medicines.

556. *Cleanliness* in all things is very necessary. The bedclothing and the clothing of the patient should be fresh and be frequently changed. All soiled clothing should be removed from the room at once, and it is advisable that it be at once placed in boiling water. A supply of fresh flowers tends to make the room more bright and cheerful.

557. *The temperature* should be kept as nearly uniform as possible. Sudden chilling is to be avoided, as well as excessive heat. A temperature of about 70° F. is usually best. If the room should, from any cause,

become too cool, care should be taken to keep the patient protected by using extra covering. Sudden drafts of cold air are to be especially guarded against.

558. *The medicines* should be kept near at hand, but out of sight of the patient. They should be properly labeled, and such drugs as are poisonous should be kept by themselves, preferably in a closet under lock and key. Spoons and medicine glasses should be kept scrupulously clean, and also out of sight of the patient. Drinking-water should not be kept standing in the room, but fresh water should be supplied each time it is required. Remnants of food should be promptly removed, and should always be thrown away, never eaten by other persons.

Proper disinfectants may be used if recommended by the physician, but they should be used in a proper manner, and under his direction. The burning of pastilles and spraying of perfume do not disinfect a room, and are usually offensive to the patient.

559. The Physician and the Nurse.—If the services of a physician be employed, it is absolutely essential that all his orders be strictly obeyed. The medicines should be given regularly and exactly as directed. No other remedies should be given than those ordered by the physician, and no heed should be paid to the recommendations of kind neighbors to give this, or that, or the other thing, because it has cured some one else. It is best to write upon a slip of paper all directions given by the physician, so that there shall be no mistakes made as to what to do or as to the exact time of giving medicines.

To the nurse, if one is employed, belongs the general supervision of the room. She sees that it is kept

cheerful and clean, that the wants of the patient are attended to, and that the orders of the physician are properly carried out. Her suggestions and wishes should be heeded by members of the family and by visitors to the patient. She should see that the patient is not annoyed or disturbed by noises or by too much conversation, and should at all times attempt to remove any feeling of apprehension or fear which he may have. Good nursing has much to do in hastening recovery from disease. It is really a carrying out of proper hygienic rules by which the patient is kept in clean, sanitary surroundings, is supplied with proper food and drink, with fresh air and sunlight, and with sufficient rest.

560. Care of the sick in contagious diseases is the same as in other diseases, with the additional caution that the patient shall be completely isolated from the other members of the family, and be denied the presence of visitors. Extra caution must also be exercised in the disposal of soiled clothing, etc., and more attention is to be paid to the disinfection of the room and its contents.

LXI.—FIRST AID TO THE INJURED.

561. **Emergencies.**—A little reliable information in regard to what to do in cases of accidents and emergencies will, at some time, probably prove of great service. To very many persons there are times when such information may be put to good practical use, and, indeed, may be the means of saving a human life. Bystanders, in case of an accident, are usually at

a loss to know what to do, and hence the simplest, but most important things, which might aid the injured, are neglected. As a general rule, whatever is done must be done quickly, and it is not always possible to wait for the arrival of a physician or surgeon. Many lives, no doubt, have been lost which might otherwise have been saved if some bystander had only known what to do and how to do it.

562. General Accidents.—When an accident occurs people usually crowd closely about the injured person. This should not be done. The crowd should be kept back so as to allow of ten or fifteen feet of free space on either side of the victim of the accident. This, besides affording plenty of breathing space, makes room for those who are aiding the sufferer, and gives them a chance to select whatever assistance they may require from the bystanders.

563. Shock.—If the person has fallen from a building or been thrown from a carriage, or injured by a blow, he may be unconscious, even though none of his bones are broken and he is not internally injured. Unconsciousness in such cases results from an effect upon the nervous system which is called "shock"; the person has fainted. The sufferer should be placed flat upon his back, with his head and shoulders slightly elevated. The limbs should be straightened out so that the heart may work with the least effort. The dress, coat, or collar should be loosened about the neck or chest. The forehead should be bathed with a little cold water, and then the person given a sip of water. Then allow him to inhale a few drops of ammonia upon a handkerchief, and gently rub his hands and feet. If the injury is not very severe, reaction will soon take place,

and consciousness will be restored. If it is necessary to remove the injured person to the hospital or to his home, a "stretcher" should be secured upon which to carry him, A settee or a shutter will answer the purpose. He should be carefully slipped upon it, and four persons, one at each corner, should lift it and gently carry him to his destination.

564. *Asphyxia* is a term used to denote suspended animation resulting from a lack of oxygen supplied to the blood. Asphyxia may be caused by submersion in water, by strangling, by the presence of foreign bodies in the windpipe, by smothering, or by the inhalation of gases.

565. *Drowning* is an accident of frequent occurrence, and whatever aid is given to the victim must be given very promptly. It is the duty of every person to know what should be done in such cases. The following steps are necessary: Recover the body as soon as possible from the water. Then laying it upon the ground turn it over so that the face shall look downward. Open the mouth and with the finger press down the tongue so that whatever water and mucus there may be in and about the windpipe may flow away. The body may be raised so as to let the head hang down, thus facilitating the running out of the water and mucus. The clothing should be quickly removed, so that there shall be no hindrance to the action of the heart and lungs.

The great problem now is to supply the blood with oxygen, and as this can only be done by the air entering the lungs it is necessary to produce the acts of respiration. This may be done artificially, one movement expanding the chest cavity, the other contracting it.

There are several ways of producing artificial respiration, Sylvester's method being probably the best. In applying this method the mouth should be kept open and the tongue depressed, the body lying flat on the

FIG 186.—ARTIFICIAL RESPIRATION. FIRST MOVEMENT.

back. Taking hold of the arms near the elbows, draw them away from the sides and upward above the head (Fig. 186). Hold them in this position a short time, then slowly bring them down to the sides, making the elbows almost meet over the pit of the stomach, and exerting slight pressure with them (Fig. 187). These motions should be repeated constantly twelve to sixteen times a minute. The first movement produces the act of inspiration, the second that of expiration.

Another method of artificial respiration and one which is of special utility if the helper should be alone, is as follows:

Lay the drowned person flat upon his back and open his mouth, placing the finger upon his tongue to keep it depressed. Now, with one hand upon the abdomen, press upward and backward until you have forced as much air as possible from the chest. Remove the hand, and air will enter the lungs. Then make pres-

sure again, and continue, repeating the operation twelve or fifteen times a minute.

Persist in the performance of artificial respiration until natural breathing has returned. The patient should then be wrapped in warm blankets or clothing, and the trunk and limbs should be briskly rubbed, so as to aid in restoring the circulation. The body should be kept warm—if necessary by the application of hot

FIG. 187.—ARTIFICIAL RESPIRATION. SECOND MOVEMENT.

cloths, hot irons, hot bricks, etc.—until complete reaction has followed.

566. *Suffocation* is asphyxia resulting from the inhalation of gases.

Carbonic acid gas, coal gas, and illuminating gas, all, if breathed, will produce asphyxia. A person who has been overcome by this form of asphyxiation should at once be carried into the open air and laid flat upon his back. The clothing about the neck and chest should be loosened, and the neck, face, and shoulders should be dashed with cold water. Artificial respiration should at once be performed, as in cases of drowning, and the limbs should be rubbed and chaffed to assist in the circulation of the blood. If the weather is such that the asphyxiated person cannot be carried into the open air, he should be placed in a large

room where plenty of fresh air is available. While artificial respiration is being performed, the lookers-on should not be allowed to crowd around, as the attending person must have plenty of room in which to work. After consciousness has returned, treat in the same way as for drowning.

567. Foreign Bodies in the Throat.—These, by pressing upon the windpipe, often produce certain symptoms of asphyxiation. A piece of food or other substance which gets into the throat and cannot be swallowed should at once be removed. Sometimes a sharp blow on the back between the shoulders will serve to dislodge it. Often it may be reached by the finger, and either pushed downward or pulled out. Sometimes the drinking of water will force it on into the stomach. If necessary, a hook may be improvised from a wire hairpin. With the removal of the foreign body the symptoms of asphyxiation will disappear.

568. Sunstroke.— Everybody is familiar with the meaning of the word sunstroke. It is a disorder to which the intemperate are specially susceptible. Weak persons who sleep in ill-ventilated rooms are more liable to it than those who are strong, or whose sleeping-rooms have an abundance of fresh air. Sunstroke is produced by high temperature. It may be from the sun, or it may be from artificial heat. Men who work in very hot rooms, as in sugar refineries, are often subject to it.

Symptoms.—Most cases of sunstroke are preceded by pain in the head, disturbed sight, muddled thoughts, pain or a sense of weight at the pit of the stomach, more or less difficulty in breathing. Soon the victim becomes insensible, the skin is hot, the face

a dusky blue, and the breathing is rapid and short. The heart's action becomes rapid, and the afflicted person often does not move a muscle.

Treatment in cases of sunstroke should be prompt. The person should be carried to a cool place, where plenty of air is available. In the shade out of doors is the best place. People should not be permitted to crowd closely about. The clothing should be loosened or removed and the person be placed upon his back with his head raised a little. Ice should be procured if possible, otherwise use the coldest water obtainable. Pour cold water over him, and rub his entire body with pieces of ice, not neglecting his head. When the heat of his body has been reduced, the cold applications may be discontinued and the body wiped dry with towels. If the excessive heat of the body returns, the cold applications must be renewed. If necessary, artificial respiration should be performed until natural respiration begins.

569. Prevention of Sunstroke.—Prevention of an attack of sunstroke may be accomplished by paying careful attention, during the hot weather, to the few following rules:

Abstain strictly from the use of any alcoholic drinks. They always render the system susceptible to an attack of sunstroke.

Get plenty of sleep in well-ventilated rooms.

Take a bath, or sponge off the whole body each night before retiring. This will keep the skin in healthy working order. Avoid drinking large quantities of cold water, especially about meal times. Wear loosely-fitting clothes. A straw hat of loose texture is advisable for the head.

Should you feel any symptoms of sunstroke, rest until recuperated in some cool place that is protected from the sun's rays.

The hot summer months is the time when the greatest care of the body is necessary. The various organs are then more liable to become deranged, and the whole system demands constant attention. Perfect digestion and perfect action of the skin are of much importance, and they act as the best preventions of sunstroke.

570. Fainting.—A person who has fainted should be laid flat upon the floor or bed, the clothing about the neck should be loosened to accelerate the flow of blood to the head, and the forehead and temples be bathed with cold water. This treatment will very soon revive him. If the person be seated in a chair when he faints, the chair with him in it should be tipped back until his head almost touches the floor. He will almost immediately revive. In cases of fainting there is an insufficient flow of blood to the head; hence the object of placing the head lower than the body is to accelerate the flow of blood to it.

571. Burns.—Burns and scalds are accidents of very common occurrence, and they should receive prompt attention. It sometimes happens that the clothing of a person catches fire. In such case the person should be thrown flat upon the ground, to prevent the flames rising and burning the face, and he should then be immediately rolled in a blanket, a rug, a piece of carpet, an overcoat, or whatever is handy that will stifle the flames.

After the fire is all out, the clothing should be removed by cutting it, and if any part of it sticks to the body, it should *not* be removed by force. The

victim should be kept as quiet as possible, as he will be suffering from shock.

For the relief of burns any of the following applications may be used, the first being probably the best if it can be obtained:

Linseed oil and lime water, mixed in equal parts.

Pure leaf lard.

Wheat flour dusted over the parts.

The white of egg applied to the parts.

Cloths kept constantly wet with cold water applied to the parts, or a lather of soap thoroughly applied.

Any one of these may be used in an emergency, but the services of a competent physician should always be employed, especially if the burn is a deep one.

Scalds are treated in the same way as burns by fire.

572. Burns by Acids.—If strong acids come in contact with the skin they will destroy it. In cases of burning by acids, the wound should be thoroughly washed with water, soap and water, or soda and water. Alkalies serve to neutralize acids; therefore earth containing a certain amount of alkali is a very useful application to acid burns. Apply it in handfuls to the injured part.

573. Burns by Alkalies.—These burns may occur from lime, potash, soda, ammonia, etc. Acids will neutralize an alkali; hence the part should be thoroughly washed with a weak acid solution, as weak vinegar, or water with a little lemon juice in it. If either acid or alkali burns are severe, a physician should be consulted, as they require the same careful treatment as other deep burns.

574. Bruises.—If a bruise is very severe, a condition of "shock" often results. In ordinary bruises

there may be much pain and tenderness, but no "shock." If there is shock, treat it as you have already learned. Cold, wet cloths should be applied constantly to the injured part until the pain and swelling have subsided. Discoloration, black or blue, generally results in the injured tissues, but this will gradually disappear. Gentle rubbing with any mild liniment will hasten the disappearance of the discoloration.


FIG. 188.—LEGS TIED TOGETHER IN CASE OF FRACTURE.

575. Fractures and Dislocations.—These are both serious injuries, and require very careful and proper treatment. A person who is not experienced and has not a knowledge of their proper treatment should never attempt to do more in such cases than to make the injured person comfortable until the arrival of competent help. If the injury be of an upper limb it should be carefully supported in a sling. If of a lower extremity, it should be kept extended and as quiet as possible. Generally by extending both limbs and fastening them both together with handkerchiefs considerable ease is afforded (Fig. 188). The same end may be accomplished by the use of a cane, a stick, or a piece of lath (Fig. 189).

Do not handle an injured limb yourself, nor allow bystanders to do so. Besides increasing the pain, the handling of it may produce a still more serious injury.

576. Wounds.—These are perhaps the most fre-

quent accidents with which you may come in contact. There are four classes of wounds with the treatment of which you should be familiar. They are:

1. Incised wounds, or those which are clean cut as with a knife.

2. Punctured wounds, as a stab, a nail puncture, or a gunshot wound.

3. Lacerated wounds, where the tissues are torn.

4. Poisoned wounds, as the bites of snakes, dogs, or insects, and the stings of insects.

577. **Hemorrhage or Bleeding** occurs in all wounds,

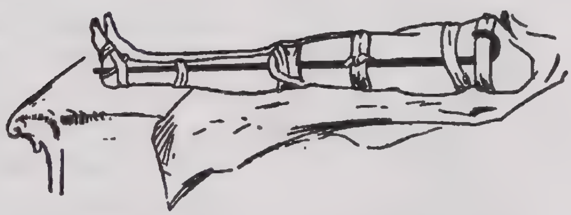

FIG. 189.—USE OF A CANE IN CASE OF FRACTURE.

and is the most profuse in incised wounds. Usually the bleeding will stop in a short while, on account of the clotting of the blood about the wound. If the bleeding is not profuse, the application of heat or of cold will help to arrest it. If, however, a large blood vessel is injured and the bleeding is abundant, firm pressure should be applied over the wound so as to diminish the flow of blood sufficiently for clotting to take place. Sometimes it is impossible to stop the flow of blood by pressure over the wound. In such cases the pressure must be applied to the vessels—above the wound, if the bleeding is arterial, below it if it is venous. To

determine as to whether blood comes from a vein or from an artery, it is important to remember that:

In venous hemorrhage the blood flows in a steady stream, and is of a dark blue color; but

In arterial hemorrhage the blood flows in spurts, and is of a bright red color.

In case of arterial hemorrhage, if the injury is in the hand, press upon the arteries in the wrist. If in the foot, press at the inside of the ankle. If of a finger, press upon either side of the finger above the wound. If the pressure upon any one of these points is not sufficient to control the hemorrhage, then pressure must be applied to the main trunk of the artery. This pressure may be done either with the fingers or by means of a *tourniquet*. The tourniquet may be quickly made by taking a handkerchief, tying it about the limb, making as large and as firm a knot as possible. Place the knot over the point where pressure is desired, then introduce under the handkerchief a stick. Twist the stick in such a way as to tighten the handkerchief until there is sufficient pressure of the knot upon the artery to arrest the hemorrhage. Figs. 190, 191, 192, and 193

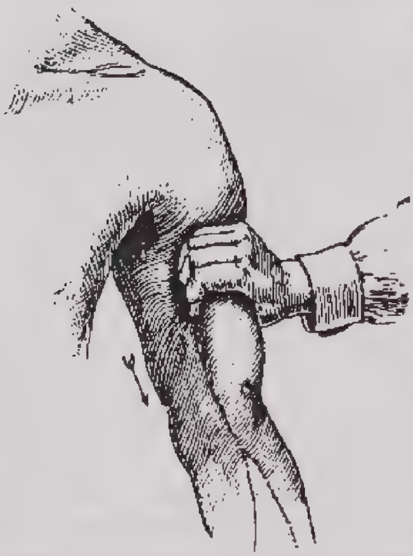

FIG. 190.—PRESSURE UPON THE MAIN ARTERY OF THE ARM.
(Dotted lines show the course of the artery.)

will illustrate the manner and position of applying pressure to the leg and arm, both with the fingers and with the tourniquet.

If the wounded person faints, treat him in the manner already designated (§ 570). If much blood has been lost, the patient should be kept quietly in bed and fed upon nourishing, easily digested foods, as beef tea, eggs, or soups, until the strength is to a great part recovered.

FIG. 191.—PRESSURE UPON THE MAIN ARTERY OF THE LEG.
(Dotted lines show the course of the artery.)

578. The Treatment of Incised or Cut Wounds is comparatively simple. After the bleeding has partially ceased, the wound should be washed with warm water. Then the edges of the wound should be drawn together and by means of strips of adhesive plaster fastened in place (Fig. 196). A better method is to take two strips of adhesive plaster (as in Fig. 195), place one upon either side of the wound, and then, by means of a needle and thread, draw them together in such a manner as to close the wound. Never cover a wound entirely with adhesive plaster or court-plaster. Apply it in strips, so that there shall be room for the removal of any discharge that may occur in the wound. If the wound be of the scalp, the hair must be carefully removed from it, and the head be shaved all around it

before it is closed up. After a wound has been closed, it should be bound up with perfectly clean white cloths, old linen or cotton being the best. Cleanliness in the treatment of wounds is of the utmost importance. The cleaner the wound is kept, the quicker it will heal. It is best that the dressing should be kept moist with cold water or some antiseptic solution. Salves, liniments, herbs, etc., should not be applied, for they will usually retard the healing process. Do not change the dressings too often. If there is not much swelling, pain, or inflammation, once in three or four days will be often enough. If the wound does not heal readily, a physician should always be consulted.

FIG. 192.—TOURNIQUET APPLIED TO THE ARM.

579. Punctured Wounds are often difficult to treat. All foreign matters, such as dirt, etc., should be removed as thoroughly as possible from the wound, and a piece of cloth moistened with water should be applied. Inflammation and severe pain are very likely to occur in this class of wounds. The punctured wounds with which you will most often have to deal are those produced by thorns, nails, or splinters. In all cases the nail, thorn, or splinter should be removed. Do not leave it to work its way out, as is often done. If you cannot get hold of it sufficiently to pull it out, take the clean, sharp blade of a penknife

and run along it sufficiently to enable you to catch hold of it and remove it. If a splinter has run underneath the finger nail, scrape the nail over it until it is very thin, then cut through to the splinter and remove it. In all cases of punctured wounds, cleanliness is absolutely necessary. Keep the parts well washed with warm water in which is a little carbolic acid, and apply cloths wet with a weak solution of the same acid. If any inflammation occurs, seek the advice of a physician at once.

580. Lacerated Wounds are those in which the flesh is torn. All foreign substances should be removed from the wound, and it should be thoroughly washed out. The edges of the wound should be brought together as much as possible by the means employed in incised wounds, and it should then be bound up in clean cloths and kept moist with a very weak solution of carbolic acid or other disinfectant. All wounds, if they do not heal readily, or if they seem at all serious in their nature, should be treated by a competent physician.

FIG. 192.—A TOURNIQUET APPLIED TO THE LIMB.

581. Poisoned Wounds.—The stings of hornets and bees are very painful and accompanied by much swelling. The application of a little ammonia, or even of a little dampened salt, will often afford much relief. Cold applications soon reduce the swelling and

remove the inflammation. Snake bites, if the snake is of the venomous kind, demand instant treatment. A removal of the poison is of the utmost importance. This may often be done by applying the mouth to the wound and sucking the poison out, an operation which can be accomplished with safety if there is no sore or wound upon the tongue or lips. If the poison cannot be removed in this way, take a knife and cut away the tissues from around the wound, then sear the surface with a hot iron. Large quantities of brandy or whisky given internally are supposed to be an efficient antidote to the poison. It would seem to be one of those instances in which one poison counteracts the effects of another.

FIG. 194.—HOW TO ARREST PROFUSE BLEEDING OF A FINGER

582. **Dog Bites** are of frequent occurrence, and as a usual thing are a source of much apprehension, although not always of danger. The danger of hydrophobia from dog bites is not so great as is generally supposed, but, as in the case of other injuries, precautions against any serious results are always advisable. If any particles of clothing are forced into the wound by the dog's teeth, they should be removed at once. The wound should be washed thoroughly, and suction may be applied to it with the mouth. The wound should always be cauterized. This may be done by taking an iron poker, a knitting needle, or other article, heating it red hot and wiping

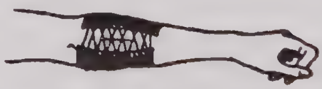

FIG. 195.—BRINGING THE EDGES OF A WOUND TOGETHER.

it over the entire surface of the wound. The iron should be very hot, so that it will destroy all the tissues in the wound. After this has been done, the application of warm poultices will be beneficial. The bites of other animals should be treated in the same way as dog bites.

583. Foreign Bodies in the Eye.—Foreign bodies, as cinders, dust, sand, pieces of metal, etc., often find their way into the eye and cause much pain and distress. They are frequently washed out by an extra secretion of tears which takes place. If not, it is necessary to remove them by some other means. By separating the lids, the particle may sometimes be seen and brushed away with the corner of a handkerchief. If the particle be adherent to the inside of the upper lid, place a match or wooden toothpick over the eyelid and, catching hold of the eyelashes, turn the lid upward (Fig. 197). This will expose the under surface of the lid, and the particle can easily be removed with the corner of a handkerchief. If the particle is imbedded in the surface of the eyeball, a tiny camel's hair

FIG. 196.

brush moistened with water will usually serve to loosen it so that it can be removed. If a piece of lime has entered the eye, wash it out at once with water in which are a few drops of vinegar.

After a foreign body has been removed from the eye, apply cold wet cloths until the pain and burning have ceased. Do not use "eye-salves" and "eye-waters," as they will usually serve only to aggravate the trouble. In rubbing the eye, always rub *toward the nose*, and never in the opposite direction.

FIG. 197.—REMOVING FOREIGN BODIES FROM THE EYE.

584. Foreign Bodies in the Ear.—If a foreign body gets into the ear, do not attempt to remove it by probing for it with any instrument, as you are only liable to push it farther in. Try to wash it out by pouring water into the ear. If this does not remove it, consult a physician. If an insect gets into the ear, it may generally be easily removed by pouring in sweet oil or glycerine. This drowns the insect, and it will soon float to the surface, and can be removed.

585. Frost Bite.—The fingers, toes, ears, or nose are sometimes more or less frozen by exposure to excessive cold. These parts are more likely than any others to suffer in this way because they are situated farthest from the heart and are most exposed. When a part begins to be frozen, the circulation of the blood in it ceases, it becomes swollen and bluish in color, then numb and pale. If the circulation of blood does not begin again within a reasonable time, complete death of the part will result. It sometimes happens

that the whole body succumbs to the cold in this way, and the person is then said to have been frozen to death. If any part, as a finger or a toe, is frozen, above all *keep it away from the heat.* The sufferer should be taken into a cold room, and the parts rubbed with snow or covered with cloths wet with ice water. After a while the parts will begin to regain their natural color, and the circulation will begin in them. They may then be dried, but the person should not go near the fire until the circulation and warmth in the parts is again normal. The treatment for a frozen person is similar, the whole body requiring this treatment. If respiration has ceased, artificial respiration must be resorted to, and persisted in until normal respiration is restored or hope is abandoned.

586. Poisons.—What is a poison (§ 179)? How does it differ from food? Name some poisons that are taken under the mistaken idea that they are foods. When does a poison produce death?

In a majority of cases a poison is introduced into the stomach and, being there absorbed, enters into the circulation, or it produces its poisonous effects directly upon the coat of the stomach. Such poisons as the acids, alkalies, arsenic, and phosphorus begin their destructive actions upon the throat and stomach as soon as swallowed. Other poisons, as alcohol, opium, belladonna, and aconite, are absorbed into the circulation and carried through the system, deranging the nervous system and destroying the various tissues. A poison which has been swallowed should be removed from the stomach as soon as possible, and whatever poison has already had time to affect the system should, if possible, be counteracted. Any-

thing that serves to counteract a poison is called an *antidote.*

587. Emetics.—The easiest way to remove a poison from the stomach is to induce free vomiting. This is done by giving *emetics.* An emetic of some kind is almost always obtainable, and amongst the best of them are the following:

1. Take a tablespoonful of mustard, mix it with a cup of water. Give this to the person, following it with copious drinks of warm water. Vomiting will soon ensue.

2. Take a teacupful of warm water, and dissolve in it as much salt as it will hold. This is a very efficient emetic if given freely.

3. Tickling the inside of the throat with a feather or the finger will often induce vomiting.

4. Sulphate of zinc is a most reliable emetic. Take as much as will lie upon a silver dime and dissolve it in a cup of water. Give at one dose, and repeat every two or three minutes until vomiting ensues.

One vomiting is usually not sufficient to remove all the poison from the stomach. Continue giving copious drinks of lukewarm water, thus continuing the vomiting and finally clearing the stomach.

588. Antidotes.—The following list of poisons and their antidotes includes those poisons which are most frequently met with. It must be remembered, however, that these suggestions are given to be of use only in cases of emergency, and the services of a physician should always be secured as soon as possible in all cases of poisoning. Give your emetics and your antidotes, however, until his arrival:

Carbolic Acid		Give emetics, then chalk or magnesia, and water. Give olive oil, flour and milk, or melted butter.
Oxalic Acid		Give chalk and water. Then plenty of olive oil.
Mineral Acids	Nitric, Sulphuric, Muriatic.	Give lime, magnesia, soap, or chalk and water often. Then olive oil or melted butter.
Caustic Alkalies	Caustic potash, Caustic soda, Ammonia, Lye.	Give lemon juice, or vinegar. Plenty of olive oil or melted butter.
Lobelia. Colchicum		Give emetics and large doses of castor oil.
Opium	Laudanum, Paregoric, Morphine, Soothing syrups, Cholera mixtures.	Give emetics. Then give plenty of strong coffee, and keep the patient awake by constantly walking him.
Aconite		Give emetics, and then plenty of stimulants, as coffee or ammonia.
Belladonna		Give emetics.
Nux-Vomica, Strychnine		Give freely of emetics.
Arsenic	Rat poison, Paris green, Fowler's solution.	Give emetics, then hydrated oxide of iron or dialyzed iron. Follow with salt and gruel.
Corrosive Sublimate		Give freely of the white of egg or flour and milk.
Toadstools, Hemlock, Tobacco,	Also various poisonous berries and vegetables.	Give freely of emetics, then stimulating drinks, coffee or very dilute ammonia.
Phosphorus	Rat poison, Matches.	Give emetics, magnesia and water, or soap and water.

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